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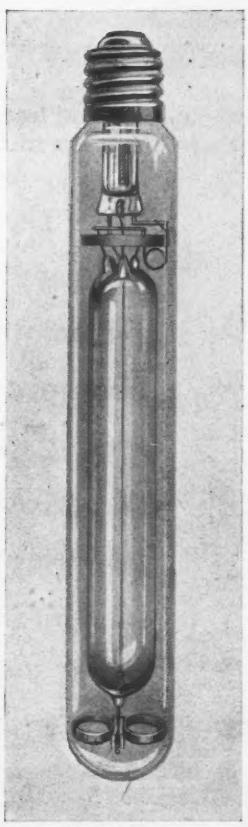

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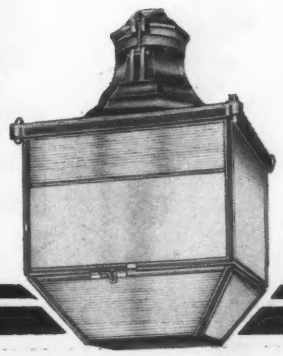

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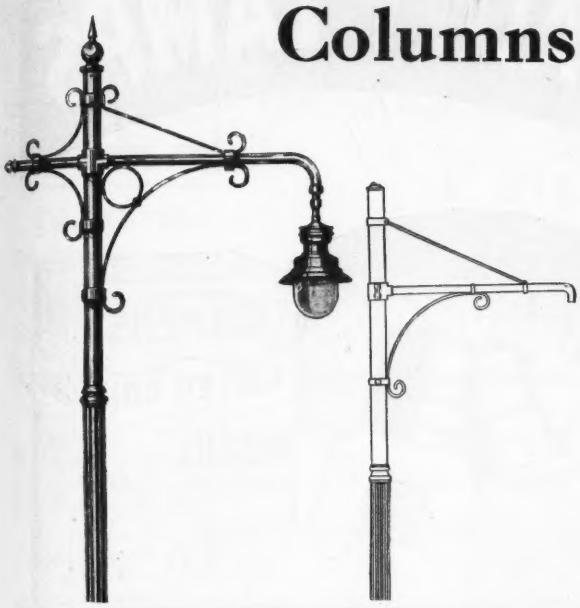

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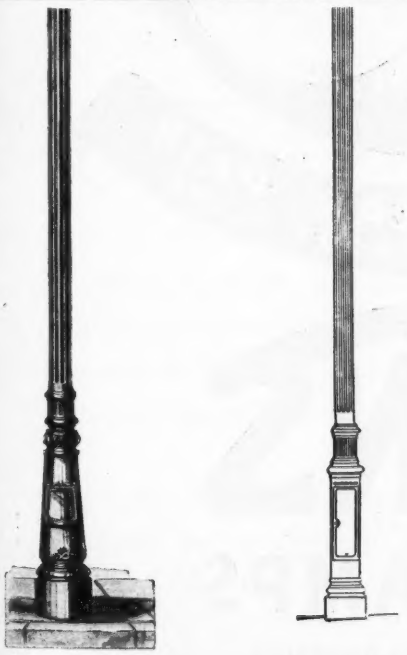

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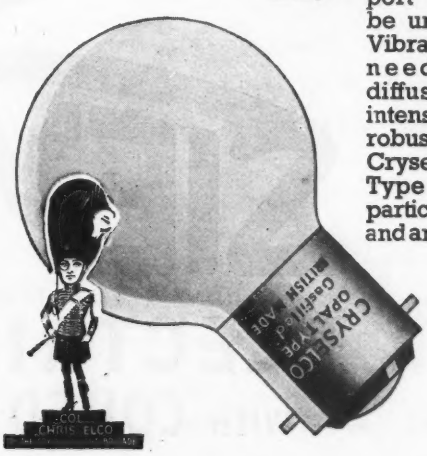

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INCORPORATED 1930

The ILLUMINATING ENGINEER

THE JOURNAL OF GOOD LIGHTING

Edited by

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A Council for the Lighting Industry?

MR. BEUTTELL, whose Presidential Address appears in this issue (pp. 359-362), voices the general impression that in time to come people will continue to use more and more light as facilities in this direction increase.

Fortunately we may well hope that increase in the efficiency of illuminants will continue to keep pace with greater generosity in their use, so that ultimately illumination even on the scale familiar during the daytime may cost us little more than we expend to-day.

Apart from such broad tendencies as these the applications of light in new directions are continually extending. Should not these developments, of great moment to the Lighting Industry, be carefully watched and fostered?

There may soon be room, as Mr. Beuttell suggested, for the services of a Council for the whole Lighting Industry—probably the greatest and most important national industry in existence at the present time.

A Wonderful New Lamp

At the opening meeting of the Illuminating Engineering Society on October 8, by common consent one of the most interesting ever arranged by the Society, the most striking novelty was undoubtedly the new super-pressure mercury vapour lamp exhibited and described by Professor G. V. Van der Werfhorst. This lamp utilises a quartz tube filled with mercury vapour and having an external diameter of about ¼ in. The length of the tube is proportional to the candle-power aimed at, the consumption being about 1,500 watts per inch of discharge so that a power of several kilowatts can be compressed into a tube small enough to be held between two fingers! A brightness as high as 260,000 candles per square inch (about one quarter that of the sun and two and a half times that of the carbon arc) can thus be attained. A luminous efficiency of 40 lumens per watt is claimed for the air-cooled lamp and 50-60 lumens per watt for the water-cooled variety. One of the most interesting features of the lamp is the fact that it exhibits a continuous spectrum, upon which the mercury lines are superimposed, thus yielding a light which is almost white in character and produces little colour-distortion. Fuller data on this remarkable lamp will be included in the description of exhibits to appear in our next issue, but in the meantime we give this brief note on its salient features.

Alfred W. Beuttell,
President of the Illuminating Engineering Society
(1935—1936).

Foundry Lighting

It is also always a good sign when one find bodies outside the Illuminating Engineering Society devoting time to the discussion of their own special lighting problems. An instance was afforded by the meeting of the London branch of the Institute of British Foundrymen held at the Charing Cross Hotel on October 2, which was attended by Mr. R. O. Ackerley, Mr. J. Clark, and several other I.E.S. members. Mr. R. W. Daniel, whose investigations in the Sheffield area will be fresh in the minds of our readers, was the author on this occasion. His paper dealt in general terms with the lighting of factories, and was illustrated by lantern slides showing typical problems, but referred specifically to foundry lighting where illuminations of considerably less than 2 foot-candles are apparently still quite usual. In the discussion some reference was made to the recent D.S.I.R. research on the degree of illumination necessary for very rough processes. It was emphasised that a relatively high illumination is really needed in foundries, where work of a highly skilled character is undertaken, and where the surroundings are dark and the degree of contrast often small. We have been told that there are over 300 foundries in London alone. Certainly the opportunities for better lighting in this field throughout the entire country must be considerable.

TECHNICAL SECTION

COMPRISING

Transactions of The Illuminating Engineering Society and Special Articles

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

The Illuminating Engineering Society

Notes on Recent Meetings & Events

Opening Meeting in London.

THE opening meeting of the Illuminating Engineering Society took place at the E.L.M.A. Lighting Service Bureau (2, Savoy Hill, London, W.C.2) on Tuesday, October 8. There was an excellent attendance, and the new departure of arranging for all exhibits to be on view at 4.30 p.m. proved useful in giving the members and friends an opportunity of inspecting the exhibits—this year more numerous than ever.

The chair was taken by Mr. H. Hepworth Thompson at 5.30 p.m. The minutes of the last meeting having been taken as read, the Hon. Secretary read out the names of new applicants for membership (see p. 358). The names of those announced at the last meeting of the Society* were read again, and these gentlemen were formally declared members of the Society.

Introduction of New President.

Mr. H. HEPWORTH THOMPSON then briefly introduced the new President, Mr. A. W. Beuttell, expressing his conviction that the Society had made an admirable selection.

The PRESIDENT, having stated his determination to do all in his power to merit the honour conferred upon him, alluded to Mr. Thompson's signal services to the Society during the past year. He had not only made helpful suggestions, which the Society was already trying to carry into effect, but had done much towards rendering these projects realisable by his efforts to secure new members. It was estimated that quite two-thirds of the notable increase in membership (about 130) during the session had been due to Mr. Thompson's personal efforts. He had been asked by the Council to make a special reference to these services, and to ask members to join him in a sincere vote of thanks to Mr. Thompson for his services to the Society during his term of office. (Applause.)

Award of Leon Gaster Memorial Premium.

The President then said that his first duty was a very pleasant one—to announce the decision of the Council to award the Leon Gaster Memorial Premium to Mr. H. N. Green for the excellent paper entitled "Recent Developments in Airway and Aerodrome Lighting," read at the meeting of the Society on March 12, 1935.

Silver Jubilee Commemoration (1934) Award.

Mr. GREEN having received the award, the President said that it also fell to him to present, for the first time, the Silver Jubilee Commemoration Award which had been granted to Mr. Ralph G. Hopkinson for his contribution entitled "The Photographic Representation of Street Lighting Installations," which was to be presented at a joint meeting with the Royal Photographic Society on December 17.

In connection with this award two other contributions had been received, from Mr. Denholm entitled "Recent Developments in Illumination," and from Mr. E. J. Ireland entitled "A Street Lighting Calculator." The President thanked the authors for these contributions, to which some reference would be made in the Journal in due course.

Forthcoming Events.

Nov. 12. DR. R. J. LYTHGOE on **Visual Perceptions under Modern Conditions** (*General Meeting of the Illuminating Engineering Society to be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1*); **6.30 p.m.**

Nov. 19. MR. E. C. LENNOX on **Public Lighting: Its Necessity and Administration** (*to be delivered at the Public Works, Roads, and Transport Congress, at the Agricultural Hall, London, N.*); **11 a.m.**

Nov. 19. Discussion on the proposal **"That the User is the Ultimate Authority on Illumination"** (*Informal Meeting of the Illuminating Engineering Society to be held at St. Ermin's Hotel, Westminster, S.W.1*); **6.30 p.m.**

Annual Report of Progress.

The HON. SECRETARY then presented the usual Annual Report of Progress, prepared by the Technical Committee, and briefly expressed the thanks of the Council to all those who had helped in its preparation.

Presidential Address.

The Presidential Address (see pp. 359-361) summarised progress made towards higher efficiencies in illuminants during the past thirty years, but remarked upon the great scope for further advances, such as would go far towards rendering possible requirements in lighting as yet unsatisfied. He reviewed

* "Illuminating Engineer," June, 1935, p. 176.

the future field of operations of the Society and suggested the formation of a Council for the Lighting Industry, by which all the needs of this industry—possibly the greatest and most important of all national industries—could be studied and met.

Photometry was well represented by the auto-photometer for street lighting measurements (Dr. S. English), the new integrating photometer compensated for obstructions (Lieut.-Col. K. Edgcumbe), and a Street Surface Brightness Meter (Mr. A. G. Brown), whilst Mr. L. H. McDermott showed the N.P.L. apparatus for determining the lower limit of natural illumination tolerable for clerical work.

Another enlivening contribution was that of Mr. A. G. Penny, who, with the aid of a new filament photographic lamp, snapshotted the President and Hon. Secretary and subsequently displayed the resultant photograph on the screen.

The meeting was concluded by an enthusiastic vote of thanks to the exhibitors, and to the E.L.M.A. Lighting Service Bureau, for their hospitality—the President remarking on the unique facilities for demonstration of the Bureau, which had once again proved so helpful to the Society.

The Exhibits.

After an interval for refreshments members reassembled to witness the demonstrations of exhibits. Although three items were withdrawn from the programme at the last minute, there remained twenty-eight distinct items, and it was creditable alike to the Chairman and the demonstrators that the programme was got through in the allotted time, i.e. by 8.30 p.m.

After Mr. W. J. Jones had given a brief account of the reconstruction of the Bureau and some of the exhibits, including those associated with "The Science of Seeing," members were treated to a striking demonstration of the new high-pressure mercury vapour lamp by Prof. G. B. Van Werfhorst, who had come over specially from Holland for the purpose. Other novel types of lamps included the new Sieray Dual Electrical Discharge Lamp, combining a luminescent mercury vapour and a tungsten filament, and various forms of electric discharge tubes yielding coloured light. The chief item in gas lighting was the new Supervia lamp with mantles in the form of a strip. Numerous forms of street lanterns and fittings for special purposes (hand-lamps, reflectors with coloured surfaces, trough lights, under-water projectors, etc.) were on view. Interesting interludes were those by Mr. E. W. Murray, who illustrated the use of miniature low voltage units for intense local lighting, and Mr. L. E. Buckell, who described some ingenious floodlighting installations in South Africa, carried out with the aid of discarded petrol tins to serve as reflectors!

A detailed account of these exhibits will appear in our next issue which will also contain the Report on Progress.
—Ed.

North-Western Area Local Section Programme

Oct. 8th. Visit to Chester Illuminations (by the courtesy of Mr. S. E. Britton, M.I.E.E., M.I.Mech.E., City Electrical Engineer, Chester).

Oct. 23rd. Exhibition and demonstration of **Recent Advances in Lighting** and allied equipment. *Manchester College of Technology, Sackville Street.*

Nov. 26th. "The Science of Seeing," by W. J. Jones, M.Sc. (E.L.M.A.). *The Engineers Club, Albert Square, Manchester.*

1936

Jan. 21st. "The World's Most Modern Fish Dock." Paper by A. G. Brown, A.C.G.I., and A. L. Whittenham, A.M.I.E.E. (G.E.C., Ltd.). *The Engineers Club, Albert Square, Manchester.*

Feb. 18th. "The Application of Subjective Methods to Lighting Problems." Paper by R. Maxted, B.E.(Elec.), B.E.(Mech.) (B.T.H. Co. Ltd.). *The Engineers Club, Albert Square, Manchester.*

Mar. 17th. Open Discussion Forum. *The Engineers Club, Albert Square, Manchester.*

Further particulars available from the Hon. Local Secretary, Mr. J. Sellars, Highways Dept., Town Hall, Manchester.

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Presidential Address

by A. W. BEUTTELL, M.I.E.E.

(Address delivered at the Opening Meeting of the Illuminating Engineering Society, held at the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, at 5.30 p.m. on Tuesday, October 8th, 1935.)

In choosing a subject for this address I was attracted by the thought that this Lighting Industry of ours is perhaps unique in possessing some possibilities, one might almost say securities, for its future growth and development which are peculiar to itself. Also I think that the industry is at a particularly interesting stage of its career. It has come to maturity: it has established its own technique on a scale which differentiates it completely from other callings; it has, so to speak, gone into business for itself; it has undertaken full responsibility in the field which it has chosen, and an independent future lies before it. It seemed, therefore, that I might use this occasion to suggest to your minds some interesting speculations on the subject of this future, for I feel that there can be no other industry in the world, with the exception, possibly, of Aviation, that has so much cause to be optimistic and confident of its own progress. I am aware that that is a big claim, and I would like to put forward some arguments in support of it.

There are two important particulars in which the claim is already staked out. The first point is that since the human being is designed to look to natural light as his normal supply, and since there is at present a very large deficiency between natural and artificial light, it would seem to follow that there must and will be a continuous human demand for more and more artificial light until this deficiency is made good.

Is there someone here who doubts this? We used to think that the human eye is designed to be satisfied, or nearly satisfied, with variations of light down to quite small values, but we do not think so now. I would remind you of the experiments made by E.L.M.A. Lighting Service Bureau, when lay subjects, left free of choice and ignorant of intensities, chose 125 foot-candles for ordinary reading, a higher value than is usually available in interiors by daylight. Moreover, surely if daylight had ever been too much, we should have been at pains to reduce it? So I must repeat my proposition that the demand is likely to continue at least up to daylight values. On the other hand the consuming public would probably be quite unable, even if it wished to do so, to pay for so much more light at its present rates. To this difficulty the second point provides the answer. As though a wise Providence, in permitting such a deficiency, had provided the means to fulfil it, we have before us the possibility of so increasing the economy with which energy may be converted into light, that the quantity of it necessary to make good the deficiency may be supplied, more or less, at the same cost to those requiring it, or at least within their economic range.

Assuming for the moment that this solution of the problem can eventually be reached, we find ourselves in the possession of two great natural advantages which are complementary and necessary to each other. For the complete solution, however, they should also balance each other. Let us take some very broad figures. If one says that the average artificial illumination, speaking particularly of interiors, is, say, one-tenth of the daylight value, he can also say that there will be a complete solution if at some future time we should be able to produce ten times as much light for the same expenditure of energy as is emitted to-day from the sources of light which are in general use.

Now, experience has shown that as the consuming public becomes more appreciative of the benefits of good lighting, it is prepared to spend independently of the amount of light it is given for a fixed sum, more and more on the wherewithal to enjoy it. If, therefore, this demand for quantity of light be satisfied without extra cost for energy, expenditure will continue to move in the direction of equipment. In such event, the growth of the whole field of lighting in the meantime will have been great indeed.

Let us see what there is to say in support of the assumption that the problem may be solved of converting energy so much more economically into light.

Shall we begin by saying that we do not recognise impossibilities until they are proved as such?

In this case it is not proved. On the contrary, so far as we can tell, the feat has already been performed by one of the least of living things, the firefly. Now, we are freeing our minds already (and we must free them completely) from some limiting notions of the past. Speaking of the electrical side, we realise that incandescent metals near the melting point will never provide the solution, but, unfortunately, having reached the limit of this line of experiment a much larger range of research appeared in the form of gaseous light. In its particular, though possibly not its final form of the gaseous discharge, we already have efficiencies greatly exceeding those of incandescent metal filament lamps, though not in white light. Let us look again at the figures. Thirty years ago, the carbon filament, say, 3½ lumens per watt. To-day, gas-filled lamps with tungsten filaments giving continuous spectra around 15 l.p.W.; vapour discharge lamps giving discontinuous spectra up to, say, 70 l.p.W. But we are only upon the threshold of this gaseous field. Between the present result and the limit of the mechanical equipment, we have all the way from 70 to 670 l.p.W. for discontinuous spectra, and from 15 l.p.W. to, say, about 250 l.p.W. for continuous spectra, or so-called white light. The progress towards greater efficiency in gas lighting during the past thirty years has likewise been very marked. Here, however, there is an even greater gap between the present performance and mechanical equivalents —though I cannot speak with authority on this subject. It seems, therefore, that here also there are very great possibilities. This is the enormous field which is handed to us for research, in which we may let out imaginations play, and wherein the biggest prizes are likely to be found. The firefly still leads the field with 600 l.p.W. of radiated output.

The fact is that we are really beginning to tackle the problem of light and its production at its foundations or what we now believe to be its foundations. We are involved in atomic physics and the mechanics of light, and, in this comparatively new field, it is not surprising that revelations are coming thick and fast.

If you will bear with me for a moment in reviewing some simple facts known to most of you already, let us consider their significance. All matter, whatever be the material, is composed of atoms which in turn comprise particles—the same particles but in different groups and arrangements. These arrangements can be upset and the consequence of upsetting them is a disturbance, which, travelling

through space and affecting the eye, causes the sensation of light, if it be within a certain range of frequency which we call the visible spectrum. Subject to this any method of disturbance will cause light. The greater the disturbance of the atoms collectively, the greater the light.

Heat will cause such a disturbance, but the difficulty with heat is that the vibrations occur over a wide range of frequencies and energy is lost in non-visible radiation. The problem, then, is to cause the vibrations so that they are all or nearly all within the visible spectrum. In the case of the firefly 92 per cent. are in the visible spectrum. Now one of the particles of an atom, an electron, can be shot out of its group altogether. In returning to its own or another group which also happens to be short of an electron, the group may exhibit radiation at any wave length. For this reason it is found that even gases usually giving line spectra or monochromatic light tend to give continuous spectra or white light when they are sufficiently disturbed. Collectively they exhibit radiation over a whole range of wave lengths.

In this ionization of gases the process is usually employed of subjecting free electrons to an electric force and relying upon collision due to their motion to create the necessary disturbance. When we consider, therefore, that there may be an almost unending variety of ways of doing any of these things and that any combination of them will produce light, which leads to the required disturbance of the atom, we realise what a vast field of possibility there is to explore and that it would not be reasonable to place any limits upon the possible results.

We have spoken of three exceptional features of lighting industry and their incidence on progress; firstly an inevitable, progressive, almost cumulative demand for our goods, secondly a well-defined territory assigned to us to conquer, rich in its potentiality to yield the wherewithal to meet the demand. Thirdly, the discovery that the phenomenon of light and its production is not dependent on the secondary and limited process by which it was formerly produced, but that it is associated with the most fundamental phenomena in the scheme of matter; so that if we are thus in touch with its first principles it would seem to offer the prospect of all kinds of discoveries not only in methods of producing light and colour but in such matters as the more skilful elimination of losses of energy.

But there are other directions in which we feel that new ground has been opened. In the physiological field, for instance, the investigation is now being seriously undertaken of the laws which govern the best utilisation of light by the human eye, or conversely those which indicate the kind of light the eye can best use. Knowledge and researches which formerly interested few but the physiologists are now brought definitely into the domain of Illuminating Engineering and we begin to devise ways of setting the results to practical use.

In a similar way we know that the science of lighting cannot be complete until we have fathomed our psychological reactions to various kinds and quantities of light. We know, for instance, that people can be made happier, that they can perform their work more cheerfully and with less fatigue under certain conditions.

Personally, I have no doubt that in the physiological and psychological fields there are no reactions which do not follow precisely laws of cause and effect, which are just as definite as they are in the physical field. The only difference is that our knowledge is not yet sufficiently advanced to be able to appreciate their composition, or, in some directions, perhaps, even their nature. Yet I have such faith in the progress of scientific knowledge that I believe it is only a question of time before these laws will be discovered.

While still on the subject of the future enlargement of our industry, there is a further point which may be mentioned in passing. Lighting becomes, day by day, a matter of higher and more specialised knowledge; its technique grows and will grow accumulatively beyond the command, and sometimes beyond the comprehension of many who, though engaged in other or composite trades or professions, have to undertake it. Much time is wasted in trying to work to unsuitable schemes. The remedy of these neighbouring professions must be to employ specialists; but, even so, because lighting is so intimately involved in their problems, they cannot give up the study of it if they are to be completely successful in their work. Therefore, we may expect them at some stage or other to join with us for the purpose of obtaining the necessary knowledge. We shall then extend to them the hand of service and friendship, and to that end we must plan and prepare so that educative facilities shall be available to them. For this it is not too early to start the wheels of organisation working, not forgetting that there is a train of wheels, and one of them is diplomacy. But, beyond this, there is a still larger field of extension, namely, the education of the mass of our fellow men so that they, in whose service indeed lies ultimately our whole work, may be awakened and fitted to derive and appreciate the greatest benefit therefrom.

And now, ladies and gentlemen, we have surveyed somewhat cursorily the territory that lies ahead of us. We have cast our eye over some of the possible assets of the future, with some satisfaction, shall we say, to ourselves. We have, however, said little of the responsibility. In appointing ourselves (and I suppose we did appoint ourselves) to the position we occupy in relation to the community, we have appropriated as our domain all that appertains to one of the fundamental amenities of mankind. Our fellows have confirmed the trust and the responsibility is ours for all time. It, therefore, behoves us in looking at the future to look also at the future of that responsibility. In the territory which is ours we have founded this Society as a central body, the only one whose constitution is completely independent, impartial, free from self or sectional interest, and, therefore, bound to public service in its greatest sense. The Society has thus assumed the role of leader, and lead it must.

To lead, however, is to think into the future, indeed it is for this reason that I ventured to choose it as my subject. Are we thinking individually and collectively far into the unhappened future, so as to discover how best to prepare for it, or are we able to do little more than to meet our everyday problems as they arise?

I am coming presently to my conclusion, and therefore I would summarise very briefly the two points of issue:

Firstly, the expansion which lies ahead of us; secondly, that which requires to be done in order to prepare for it.

In putting to you the first issue, let me resume my role of optimist and endeavour to picture in imagination what the industry of light will be at some time which none can foretell, for that depends on how quickly we succeed in this world of affairs in smoothing the path of progress. It will have an honoured place amongst the greatest industries. Technically, it will be established as one of the leading professions integral in itself because too great to be included in any other. Its consulting engineers or physicists will constitute a recognised and important profession so that illuminating engineering can be chosen with confidence as a career for new generations. At the scientific end it will have made an organised contact with those researches of pure science which are now largely carried on quite independently of it. There will be a Government department, or at least a sub-department occupying itself primarily with light as it affects the public welfare. Consumers' tariffs will be rationalised on a uniform basis designed to en-

courage, as some of them definitely do not, the extension of lighting loads. As already suggested it will progress in its ability to satisfy a naturally increasing demand for more light, and in so doing it will increase in magnitude and power.

Amongst those matters which are more difficult but which may possibly be regarded as desirable ends to achieve are the following:—

The practice of co-operation through a council of the whole industry aided by its allies so that each shall recognise with practical effect the problems of all for the benefit of the whole.

The establishment of minimum codes with statutory effect.

Last, but not least, the organised extension of research.

Now, as to the second issue, namely, what is required to be done in the process of attaining these ends, or any of them. Surely it is that there must be some organised body to plan and think for the future, and I submit that that body should be, or be promoted by, this Society.

Experience shows that without some kind of organised co-operation industries tend to settle down into sections with sectional policies, each section looking to itself, as indeed is almost to be expected.

I am aware that there already exist bodies, some very influential, whose concern it is to promote the general welfare and advancement of the gas and electric industries. In particular I recall the recent proposals originated this year at the Electrical Convention in Bournemouth, which are still in course of development. The aims of such bodies are, however, necessarily at once broader in some respects and more restricted in others than those of the organisation I visualise—in that (a) they are concerned with many matters other than lighting, and (b) they necessarily confine themselves to the section of the lighting industry which they represent. A policy is wanted, not of the few, nor of a section, but of the industry. It is very recent history that another of our greatest industries accomplished a belated but successful reconstruction although after reaching a dangerous condition. How much easier then and more promising of results for us.

And now may I endeavour to disarm, if I can, a little criticism? Many ideas have been mentioned which are frankly either optimistic or idealistic, some of them may be called visionary. This was premeditated because I think that the most creative and constructive thinking proceeds in the first place from an idealistic basis. We all require occasionally a little exercise in stirring the imagination and stretching the mind. Such thoughts, however, if they are to go further and be of practical use must be tempered with a sound recognition of material facts. We are most of us engaged in business. The time may come when business will be more consistent with idealism than it is to-day; in the meantime, whilst at any moment business must be as usual, the use can gradually be changed so long as it is for the better.

My plea is for more concentration on the corporate side of the industry as a whole, not only by those who already devote much time to it, but particularly by those who do not. My justification is that picture of the future that each of us may be able to paint, but let us have some picture and let us study it. The corporate side where it is least self-interested is represented by the Illuminating Engineering Society; the kind of responsibility we have referred to is vested mainly in it. It seems to require strengthening, not in regard to its own private affairs (we are already seeing to that), but in regard to its possible influence upon the industry generally. For this, one of its greatest needs is that its younger members should become active in the corporate sense, and that they should become articulate. But yet another is that at the other end many of our industrial leaders who are now absent from our Councils should be with us. Not only should we value their help, but I am sure that they would have something to gain. One may stand ever so aloof from the central organism of his particular community, but one thing he cannot do is to abstain from the benefits or the ills of its doings according as they be good or bad. I appeal also to them. It may be that if any of the ideas that have been sketched should lead to a programme of construction they and many others would be more interested.

It will be for you to say whether consideration of these matters is desirable. It is not forgotten that many of them, simple to do in some directions, are delicate and intricate in others; nor do I underestimate the practical and business difficulties which have to be overcome, or the fact that some of these things cannot be done at all until the ground has been successfully prepared for them. It is, however, suggested that it is not too early to begin to design the successful corporate machine of the future, nor too late to repair some defects in the present one. There are at present many organisations which are more out of touch with the Society than they should be; so much the better, the more defects in the machine the greater the result when they have been repaired.

Nor is there any suggestion that the Society should change its character or its role; it is rather that it should live up to it. In commercial questions it would not act, but promote or suggest or influence, though always so as to keep commercial and financial development where it ought to be—beyond its own borders.

I would sum up by saying that our future is worth every effort. We were reminded recently of some words of Mr. C. C. Paterson, in July, 1929, that we should avoid giving our successors reason to say of our generation "illumination had they but no insight, much light but little vision." We are in 1935, and I do not know if he is satisfied with what has intervened. We have done much, but I am sure we would all like it to be said by those who in the far future will look upon us as early pioneers, that whatever our difficulties may have been whilst we tried to visualise the complete and wonderful structure that was to be, at least we gave them foundations organised in plan, sound in material, and in their construction well and truly laid.

Visit to the National Portrait Gallery and the National Gallery

On Tuesday, October 22, members of the Illuminating Engineering Society visited the National Portrait Gallery and the National Gallery (London). On arrival at the National Portrait Gallery they were welcomed by the Director, Mr. H. M. Hake, who gave a short address on the lighting arrangements. Mr. R. R. Holmes and Mr. Pledge, who had been responsible for the design of the special fittings adopted, briefly explained the chief technical details, after which they and Mr. A. D. Fitz-Gibbon (H.M. Office of Works) conducted parties over the Duveen gallery in which artificial lighting had recently been installed. At the National Gallery Mr. A. D. Fitz-Gibbon made a few introductory remarks, and Mr. W. M. Peirce, Mr. E. L. Damant, and others on the staff of the General Electric Co., Ltd., who had been concerned with this installation, were present to act as guides. We hope to include a short account of the lighting of the section of the National Portrait Gallery visited in our next issue. The new lighting of the National Gallery has already been described. (See "Illum. Eng.", May, 1935, p. 161.)

The thanks of the Society are due to the authorities and all who helped in the arrangements for this visit. It is to be hoped that the use of artificial lighting, on which so much care has been expended, will encourage many people who cannot readily visit these galleries during daylight hours, to do so in the evening.

Report on Proposals for Improving the Position of The Illuminating Engineering Society

(Presented at the Special Meeting of Members held in the Lecture Theatre of the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6.30 p.m., on Thursday, September 26th, 1935.)

Introduction.

IT will be recalled that various proposals affecting the future of the Society were made in the Presidential Address, delivered at the opening of the session. The Council referred these suggestions to a special committee consisting of the President (Mr. H. Hepworth Thompson), the President-Elect (Mr. A. W. Beuttell), the Hon. Secretary and Hon. Treasurer (Mr. J. S. Dow and Mr. Percy Good), Mr. C. C. Paterson (Past President) and Dr. J. W. T. Walsh (Past President), on whose deliberations the report now issued by the Council is based.

At the outset it became apparent that the desirability and feasibility of some of these proposals depended on the view taken of the nature and functions of the Society.

Scope of the Society.

It is, therefore, expedient to recall, firstly, that the scope of the Society, as at present indicated in the Constitution, should be interpreted in the widest possible sense, and as covering all applications of light, natural and artificial.

Its field of study should thus be regarded as including not only the use of artificial light for purposes of illumination, but also such matters as access of natural light into buildings; the effect of light on vision; colour; the application of light, in the form of signs or other devices, to attract attention or produce decorative effect; the optical projection of light by lanterns, cinema projectors, motor headlights and searchlights; applications of visible and invisible radiation in the interests of health, agriculture, and horticulture; the production of fluorescence (either for decorative purposes or as a means of analysis); the mechanics and composition of light. There is, indeed, no aspect of light that should be regarded as beyond the scope of the Society.

Secondly, it should be borne in mind that the Society, as at present constituted, is primarily a "cultural" body. It aims at interesting users as well as experts, and the foregoing list of subjects alone suffices to indicate the variety of professions and occupations which may fitly be represented in its ranks. At present the membership of the Society is drawn very largely from leading firms in the lighting industry, either makers of lamps and lighting equipment, or gas and electric supply undertakings. It also includes consulting engineers, engineers-in-charge, and others who act as links between the producer and the user; a few others, such as architects, medical men, and teachers whose interest in lighting is occasional; and others again who are not vocationally concerned with illumination at all, and whose interest is simply that of the consumer.

Need for Increased Membership.

In so far as it welcomes all these various classes the Society may fairly hope to secure, ultimately, a very much larger membership than at present, a condition which is essential if its aims for the future are to be attained. It is evident, however, that success in this direction will depend on the extent to which it can meet the requirements of these different classes of people, some of whom may be interested almost exclusively in one special phase of lighting, at present only very occasionally discussed at the Society's meetings.

Formation of Special Sections.

With a view to broadening thus the interests of the Society, the creation of a series of sections, each dealing with some specific field of work, is proposed. As a first step the formation of sections on (1) Architectural and Decorative Aspects (including Fittings Design); (2) Public Lighting; (3) Physiological Aspects of Illumination; and (4) Photometry, is suggested. During the Session occasional supplementary meetings, in addition to the usual monthly meetings, would be arranged by these sections. Although designed to appeal mainly to certain groups, these supplementary meetings would be open to all members of the Society, and the Society should be in a position to publish all contributions presented thereat. Other sections might be formed if a sufficient demand for them was found to exist.

Other forms of meetings such as might enhance the value of the Society to members are being considered, for example, occasional lectures by eminent scientists on subjects of general interest, for which a fee would be paid, and informal meetings or debates such as would prove attractive to the younger members. It has also been suggested that the number of visits, which invariably prove popular items, might be increased.

In framing its programme, however, the Society should bear in mind that its task is two-fold. It should serve as the home of research on all aspects of light and its applications, but it should also educate in the sense of making known the fruits of its work to the multitude. Its prestige depends in a great measure on securing original papers of high scientific and technical merit. Such papers, however, whilst of great value to the expert may be restricted in their appeal. It may, therefore, be necessary to arrange other meetings, demonstrations, and lectures intended to make a wider and more popular appeal—to interest the community in illumination and to impress on it the value of good lighting in its daily life.

Publication of Transactions.

This duality of purpose should again be recognised in connection with the means of giving publicity to the Society's work. As remarked in the Presidential Address, the existing arrangement has, doubtless, served the Society well. Yet it is becoming evident that the Journal is at present endeavouring to serve two functions which can only be combined with difficulty—namely, to record the papers and discussions of the Society, often of a highly technical character, and at the same time to offer a means of popular exposition of its ideals. The difficulty is one that may become greater as time goes on, since the amount of material requiring publication must tend to increase as more "special sections" of the Society are formed. It is now suggested that the existing Journal should be divided. The Transactions of the Society should be issued separately for the benefit of members, with all due attention to dignity of form,

accuracy, and scientific character. The Journal should operate as a medium for conveying the Society's message in a popular form to a wider circle. Both should be available to all members of the Society, but the Journal would have a wider field to cover and would circulate amongst people outside the ranks of the Society, as it does at present.

One other step recommended in the Presidential Address, the appointment of a publicity agent to ensure that the work of the Society receives adequate attention in the Press, has already been taken

We come now to others equally important but less easy to realise in the immediate future.

A Library of Books on Illumination.

We all hope that in time to come we may be in the fortunate position of owning a home of our own. This ideal, naturally, could not be realised without a very much larger membership than at present. There is, however, one feature of such a home which might be entered upon in a modest way—the formation of a library of books dealing with photometry and illumination. Before very long it might be possible to hire and equip a suitable room for the purpose, but even now the formation of a nucleus of books might be commenced. This, indeed, is a step that should not be long delayed, as there are many types of useful books which are already becoming scarce and are likely to become more difficult to acquire.

Educational Effort.

Next, we have a feeling that the Society has not explored sufficiently the encouragement of research and education in illuminating engineering. Through our Technical Committee we have just recently made a beginning towards initiating investigations. An inquiry now being made at our suggestion by a post-graduate student at Birmingham University is a hopeful sign, and the Council would gladly encourage other approved researches by financial aid on a modest scale where this would be helpful. One more ambitious project which we would like to realise when the financial resources of the Society permit is the initiation of a Travelling Scholarship, or, alternatively, a Research Scholarship.

The course of lectures on illumination initiated in London in 1932 is typical of the kind of effort which this Society ought to encourage in connection with education. It appears that at present the demand would not be sufficient to enable such a course to become an annual event, but doubtless this might become practicable in the future. In the meantime more might be done by means of occasional lectures on special subjects, such as would help to interest students in our work and might serve to gain recruits for the Society.

A Diploma for Students.

The view of the Society and its membership indicated above evidently makes the imposition of an examination as a condition of membership inexpedient. It is suggested, however, that the Society might well consider—not as a condition of membership, but merely for the benefit of those who would welcome some indication of proficiency—the organisation of an annual examination in illuminating engineering, on the results of which an elementary diploma might be granted.

Again, it has been suggested that ultimately some form of distinction (such as the title of "Fellow") should be granted to those members who are recognised to be experts on lighting. In order to be of value, however, such an award should be based on some tests of knowledge and experience.

We have left to the end two questions, both of great importance but both of considerable difficulty.

The first of these is the relation of our Society to other bodies which are pursuing similar fields of work. The Special Committee is unable at present to make concrete proposals on this topic, but is exploring possible methods of avoiding apparent division of authority or overlapping of effort.

Proposed Change of Name.

The second question, which may be in some measure influenced by the first, is the choice of a new name for the Society. It is felt that the existing name is open to two main objections. In the first place it does not adequately convey the wide field of knowledge with which the Society professes to deal. In the second place it suggests a purely technical outlook and thus may deter from joining the Society many whose co-operation would be both helpful and welcome.

The Special Committee has discussed this question at considerable length. It has not been successful in finding a new name that appeals as an entirely satisfactory substitute for the present one, but it is putting forward the description that secured the greatest measure of approval, namely "The Society of Lighting." This has at least the merit of eliminating the word "engineering," to which objection is frequently taken by those interested mainly in illumination as an art.

Summary of Recommendations.

At this stage it will be helpful to recapitulate the main suggestions so far made.

The conclusions which seem likely to meet with general acceptance and to prove capable of application in the immediate future are:—

(1) The scope of the Society, as at present indicated in the Constitution, should be interpretated in the widest possible sense, as covering all applications, of light, natural and artificial.

(2) The Society is primarily a "Cultural" body. It aims at interesting users as well as experts.

(3) A broader title, omitting the word "Engineering" is, therefore, desirable. "The Society of Lighting" seems the best name suggested at meetings of the Committee (though not considered completely satisfactory).

(4) In order to broaden the interests of the Society sections on (1) Architectural and Decorative (including Fittings Design); (2) Public Lighting; (3) Physiological Aspects of Illumination, and (4) Photometry, should be formed. Occasional supplementary meetings are suggested. Also occasional lectures by eminent scientists on subjects of general interest such as Physics of Light Production, for which a fee would be paid. Special meetings or displays designed to illustrate the nature of good lighting and its value to various sections of the public might also be arranged.

(5) The Society should be in a position to publish all contributions presented at such supplementary meetings.

(6) The rearrangement of the Journal, so as to permit separate presentation of the Transactions of the Society, under the conditions indicated above.

(7) The formation of a library of books dealing with Illumination seems desirable. This could only be organised by degrees, but in the meantime, gifts of books might be invited and efforts made to obtain certain books, such as those dealing with the historical aspects of lighting, which may become more difficult to obtain as time goes on.

All the above proposals could be put into operation without any change in the articles and bye-laws

of the Society with the exception of the change of name (3); for this the consent of members would have to be formally expressed in the manner indicated in the Constitution, and the approval of the Board of Trade would have to be obtained.

Amongst further steps which, it is hoped, will be approved in principle, but which, it is recommended, should be deferred until conditions are more ripe for their adoption are:—

(8) The establishment of an Annual Course of Lectures on Illumination, (9) the provision of a Travelling or Research Scholarship, (10) the award of a Diploma based on an elementary examination in illuminating engineering, and (11) the award of a distinction (such as the title of "Fellow") to members proved to have expert knowledge in the application of light.

There remains the final question—(12) Relations with Other Bodies—which has only been very imperfectly explored as yet.

Conclusion.

The details of most of these suggestions will require further study. What is now desired is the approval of members on the general principle.

The expenditure on the proposals contained in items (1) to (7) can probably be contemplated with a moderate increase in membership, but the more extended developments outlined can only be brought into operation with a substantial increase in the financial resources of the Society. It is therefore for those interested to continue their efforts to increase the Society's membership.

It is also hoped that members will take this opportunity of suggesting any further steps that occur to them for raising the prestige of the Society or rendering it more useful to its members.

DISCUSSION

Mr. H. HEPWORTH THOMPSON, who as President for the session 1934-1935 had been largely responsible for the proposals covered by the above report, opened the proceedings by a brief explanatory statement. He concluded by suggesting that the various recommendations should be presented in turn for the approval of those present.

Recommendation (1) relating to the scope of the Society was approved without comment.

The second recommendation gave rise to some discussion, especially in regard to the meaning of the word "cultural." Several of those concerned with the drafting of the report explained that the term was used primarily to indicate that the Society was organised on broad lines to foster knowledge of and research in light and illumination, rather than to advance professional status—the latter a condition that would necessarily restrict membership if it were regarded as a primary one. Ultimately this view found expression in an amended version, proposed by Lt.-Col. KENELM EDGCUMBE which met with general acceptance, and was as follows:—"The Society is primarily a body for the advancement of knowledge of lighting in all its aspects. It aims at interesting users as well as experts."

Recommendation (3) relating to a change of title for the Society gave rise to a considerable amount of discussion. Various alternative names were suggested, but neither these nor that tentatively proposed in the report ("The Society of Lighting") secured substantial support. A proposal that the existing title "The Illuminating Engineering Society" should be retained, on being put to the meeting, was approved by the great majority of those present. In accepting this expression of opinion, the chairman remarked that the broader title had been suggested in an effort to comply with suggestions made by members from time to time, and Mr. C. C. PATERSON, a member of the Special Committee, recalled the difficulty experienced in finding a name that satisfied everyone. It was agreed, therefore, that the decision to retain the existing title, even if not entirely satisfactory, was the only possible course.

The proposed formation of sections (4) was next discussed. It was explained that such sections would be composed of members specially interested in certain subjects which, in a technical sense, might deserve discussions several times during the session and yet could only figure infrequently on the main programme. They were, in fact, designed to meet the needs of specialists. Any such additional meetings would, of course, be open to all members of the Society, and, conversely, no doubt, papers of outstanding merit inviting a wider interest would receive consideration by the Papers Committee when arranging the ordinary monthly meetings. Some discussion took place in regard to the choice of subjects for sections. In particular the point was raised whether meetings devoted to public lighting might not overlap those of the Association of Public Lighting Engineers. In this connection the HON. SECRETARY explained that whilst that Association was able to arrange an excellent annual conference, it could not so easily arrange periodical meetings, as its membership was widely distributed. If the occasional sectional meetings were arranged he hoped that they would also be useful to the Association and that its co-operation would be forthcoming.

Ultimately the idea of forming sections was approved in principle, on the understanding that the Council would determine which sections were most feasible and desirable, and proceed with their formation as opportunity arose. The other steps indicated in (4) were also agreed.

Items (5) and (6) were approved in principle. Some discussion on the form of the Transactions took place, some speakers preferring a smaller size of page than at present adopted for the journal. The HON. SECRETARY explained that, if desired, the Transactions could be ultimately given this form. For the moment, and as a transition step, however, it seemed more convenient and economical merely to separate out the pages devoted to the Society's meetings so that they could be circulated at the same time as the journal.

The final recommendation relating to the formation of a library (7) was carried without discussion.

Mr. H. HEPWORTH THOMPSON'S announcement that he proposed to contribute fifteen guineas to this purpose was received with acclamation by members present who warmly expressed their appreciation of this generous gift.

In the course of the discussion some reference was made to other matters covered by the report, notably to the desire expressed that some recognition should be made of the knowledge and acquirements of members who were definitely experts in illuminating engineering. In this connection the projects of conferring a diploma or the title of "Fellow" were discussed; in regard to the latter distinction it was urged that any such title should not be too widely granted, but only to a limited number of members recognised to possess the requisite qualifications.

Modern Views on Street Lighting and their Relation to Visibility

by F. C. SMITH, F.C.S., Assoc. M. Inst. Gas E. and K. F. SAWYER, B.Sc. *(Gas Light and Coke Company)*

(Delivered at the Twelfth Annual Meeting and Conference of the Association of Public Lighting Engineers, held in London, on September 11th, 1935.)

Introduction.

Few aspects of illuminating engineering have received more attention during the past three or four years than the technique concerned with the lighting of our public thoroughfares. In this country and abroad the problem has been studied intensively, and gradually there appears to be emerging a clearer appreciation of the many factors involved.

A superficial examination of the expressed views of various workers would make it appear that their resulting practice differs fundamentally. In reality it seems that a fair measure of agreement exists, and that the essential differences lie in the degree of relative importance attached to the various factors. In addition we believe that much work remains to be done, especially in a direction which, up to the present, has been somewhat neglected, possibly on account of the inherent difficulties in the investigation. The factor referred to is the *kinetic term*, which has been recognised and referred to by M. Cohu and others, and this is not determinable solely by the usual physical measurements familiar to lighting engineers. It will be agreed that the appraisement of a street lighting installation solely in terms of measurements made by stationary observers upon stationary test objects, may not represent the actual working conditions. Such measurements do not take into account the kinetic aspect and its effect upon the physiological and psychological response of the road users. Even if all the factors influencing the effectiveness of street lighting installations were known, assessed in relative importance, and were under control, the individuality of streets would still require a variety of technique in order to ensure optimum conditions.

For this reason it is futile to expect any street lighting specification to cover completely the many and varied conditions met with in practice, and it must remain with the public lighting engineer to combine the essentials of the specification with his knowledge of the practical requirements of the street in question.

The purpose of this paper is:—

(a) To enumerate the factors as far as they are known, which are of importance in promoting good visibility.

(b) To stimulate interest in the further study of the kinetic aspects of the problem, and to this end a film and photographs are presented.

(c) To review the British Standard Specification in the light of the more recent work and experience of lighting engineers.

In addition an appendix is added, which gives details of a rapid method for constructing iso-foot candle diagrams, which we hope may be of interest to lighting engineers.

Promotion of Visibility.

It is commonplace to say that the object of street lighting is to promote visibility, but in this simple statement is inherent one of the greatest difficulties of the problem.

Anyone connected with street lighting will understand in a general way what is meant by visibility, but the term has never been defined in an entirely satisfactory manner. It seems we mean that when visibility is good one can see objects with ease, but no one, as far as we are aware, has yet been able to propose a scale of numbers which can be determined by physical measurement, and which will assess the order of visibility in a given thoroughfare.

The absence of such a scale is a fundamental difficulty in appraising the true "revealing power" of a street lighting installation, and has compelled the adoption for specification purposes of measurable criteria, such as candle-power, illumination or brightness.

Much of the criticism directed against the British Standard Specification for Street Lighting is due to failure to recognise this inherent difficulty. Lighting engineers have become so accustomed to such terms as foot-candles, etc., that there is danger of losing sight of the fact that these figures are but substitutes for something which, in our present state of knowledge, cannot be measured directly.

As is well known, the ability to see an object depends upon a contrast in brightness between the object viewed and its background, the smallest perceivable difference of brightness depending upon the absolute level of the field brightness. Under favourable circumstances the smallest perceivable difference of brightness may be as low as 1.0 per cent. of the field brightness, but when glare is introduced in the field of vision this percentage increases rapidly. The cause of this decreased sensitivity is referred to as disability glare.

Other factors affecting visibility will be considered later in this paper, when the kinetic aspect is further developed. So far it is clear that the aim of a designer of an installation should be:—

(1) To secure good contrast in brightness between the object to be seen and the background.

(2) To avoid loss in available contrast consequent upon disability glare.

The first part of this paper is concerned with a review of the factors influencing the contrast the lighting engineer can provide, and consideration is given as to how far these factors are under control. For the sake of clarity, the term contrast in this paper means the ratio of the brightness of the object viewed to the brightness of the appropriate background. It is convenient, therefore, to study in turn the conditions affecting the brightness of the object and that of the background.

Brightness of Object.

This is dependent upon the flux of light falling upon, and the reflection coefficient of the object. The former is under control in so far as the lighting engineer can arrange for practically any required distribution, and can provide the flux required, assuming no financial limitation, but he has no control of the reflection coefficient of the object he has to illuminate.

Brightness of Background.

It becomes important at this stage to study the constitution of the backgrounds, and it is here that the public lighting engineer is called upon to exercise considerable individual judgment.

Any or all of the following may constitute the background at any moment:—

(1) Road surface, pavement, or grass verge.
(2) Buildings, hoardings, fences, trees, etc.
(3) Fields and similar open spaces.
(4) Sky.
(5) Other vehicles.

It must be recognised, however, that under practical conditions the background viewed is always changing, and, in consequence, the lighting of any given background without regard to the requirements of other equally important backgrounds, may prove disastrous.

There has grown up, in our opinion, a tendency to regard the road-surface as the all-important background, and, in consequence, to under-estimate the importance of others.

In order to obtain data as to the relative importance of these backgrounds, a film camera, operated by a photographer sitting next to the driver in a saloon car, was employed.

The driver was instructed to drive from Nine Elms-lane to Harrow. Both the driver and the operator were quite unaware of the object of the film, and the camera was operated for a few seconds every ten seconds along the route without regard to traffic conditions within the field of view.

From a negative of this film a print was made of every twentieth frame.

From these photographs a careful analysis was made of the composition of the background, against which any object in the roadway must be seen. The background in every case consists, in whole or part, of:—

(1) The road-surface.
(2) Pavement, including kerb.
(3) Buildings bordering the road, and including trees (not necessarily lining the road); fences and hoardings.
(4) Other vehicles.
(5) The sky.

The outline of each object was divided into ten, and the number of tenths of this outline seen against each of the five components of the background, as detailed above, was computed. About 360 objects were so examined, and the average results are shown in Tables I. and II.

TABLE I.

Table showing relative importance of the road as background.

	Total number of objects considered.	Whole outline of object seen entirely against road.	No part whatever of outline of object seen against road.	Outline seen against all or some of the various backgrounds mentioned.
		%	%	%
Mechanically propelled vehicles ...	206	1.9	3.4	94.7
Carts, trucks, vans, etc. ...	53	Nil	7.5	92.5
Cyclists ...	51	Nil	7.9	92.1
Pedestrians (in road) ...	49	Nil	14.3	85.7

The last column of Table I. requires further analysis to show how the outline is distributed over the various backgrounds. This is carried out in Table II. hereunder.

TABLE II.

Table showing average percentage of outline of object seen against the various backgrounds.

	Road.	Pavement.	Buildings.	Other Vehicles.	Sky.
Mechanically propelled vehicles ...	33	8	41	12	6
Carts, trucks, vans, etc. ...	22	28	46	4	Nil
Cyclists ...	29	22	37	10	2
Pedestrians (in road) ...	33	13	34	20	Nil
Pedestrians (on kerb, about to enter roadway)	12	42	46	Nil	Nil

The control that can be exercised over the brightness of the viewed object has already been discussed; it remains to consider how far the brightness of the appropriate background is under control.

Road Surface.

The brightness of the carriage-way at any point is dependent upon three factors:—

(1) Intensity of the light in a given direction.
(2) The material composing the surface and its condition at that point.
(3) The angles of incidence, reflection, and bearing subtended by the observer at the point.*

In regard to (1), this is entirely dependent upon the distribution of light and for practical purposes is completely under control.

In regard to (2), this is not primarily under control, although it is to be hoped that increasing recognition will be given to requirements of the illuminating engineer in this connection in the future, that is, assuming them to be consistent with economic and safety conditions. In point of fact, however, the lighting engineer must always be called upon to deal with many and varied types of surfaces. Moreover, the condition of any given surface is not constant, the

* See J. M. Waldram.—"Road Surface Reflection Characteristics and their Influence on Street Lighting Practice."

weather, usage, and age all contribute to the uncertain condition of the surface. Variations in camber, gradient, etc., have also to be contended with.

Considerable work has been done in this country and abroad to obtain quantitative data in regard to the reflection characteristics of certain surfaces.

The following table has been abstracted from the results given in a recent communication from the French Secretariat to the International Illumination Congress, and serves to illustrate the marked effect of varying road surfaces upon the resultant brightness.*

Surface†	Angle of Incidence.	Angle of Reflection.	Angle of Bearing.	Reflection Factor.
Compressed Asphalt ...	40°	40°	0	0.08
		60°	0	0.083
		75°	0	0.09
		85°	0	0.115
do.	87°	40°	0	0.16
		60°	0	1.5
		75°	0	11.0
		85°	0	40.0
Wood Blocks	40°	40°	0	0.06
		60°	0	0.075
		75°	0	0.09
		85°	0	0.12
do.	87°	40°	0	0.13
		60°	0	0.8
		75°	0	3.0
		85°	0	8.0
Bitumen	40°	40°	0	0.08
		60°	0	0.095
		75°	0	0.105
		85°	0	0.12
do.	87°	40°	0	0.18
		60°	0	0.7
		75°	0	3.0
		85°	0	15.0

† Surfaces removed from Paris roads.

Assuming a brightness in arbitrary figures of 40° has to be achieved at a given point on the road receiving light from one source at an angle of 87°, and viewed by an observer at an angle of 85° (reflected and incident rays in the same vertical plane), then the necessary candle-powers to achieve this result on all three of the surfaces referred to in the table will have to bear the following proportionality to each other:—

Surface.	*Required Intensity.*
Compressed Asphalt	1
Wood Blocks	5
Bitumen	2.7

As far as we are aware, no measurements have been published to show how the reflection factor will change with varying conditions of weather and usage, but it is common knowledge that the appearance of certain surfaces changes in a marked degree in wet weather, and this would indicate considerable changes in reflection values, possibly for certain surfaces of the order of 10 to 1. It is apparent, therefore, that the designer will be called upon to light surfaces which differ in a marked degree, and that reflection factors will change with new road dressings, usage, and weather conditions. Over these factors he will have little or no control.

* Premier résultats des essais effectué par la Société pour le Perfectionnement de l'Eclairage pour la determination des caractéristiques refléchissantes des divers revêtements utilisés dans les voies publiques. By MERRY COHU.

Photograph I., which will be referred to again later in this paper, is of interest in this connection. The

Photograph 1.

left-hand side of this road has recently been redressed. The effect upon the reflection properties of the road is apparent.

Buildings, Hoardings, Fences, etc.

The designer, having surveyed the ground for the proposed installation, must then assess the importance to be attached to these backgrounds. In the case of a long straight road with buildings set back a considerable distance, these, in the writers' opinion, are of secondary account, but at bends and road junctions, they are often of paramount importance.

As is well known, much can be accomplished by the careful arrangement of sources (i.e. on outside of bends, etc.), and the distribution of the source can be modified so as to illuminate the appropriate surface. Frequently this may have to be done at the expense of test point illumination, in so far that it is desirable to allow the flux that would normally be redirected towards the test point to fall upon this background. It is unfortunate that some of these backgrounds, in practice, have low reflection factors, but much may be accomplished by co-operation with Municipal Engineers and the owners of bordering property.

Photograph 2 is of interest in this connection. The road in question is fairly well illuminated. Danger arises from the nature of the background at the bend

Photograph 2.

of the road. Although it may not be apparent from the photograph, a car is standing at this point and is almost entirely invisible—a typical illustration of danger arising from ill-considered lighting of appropriate backgrounds.

Photograph 3.

Photograph 4.

Photograph 3 is of the same place. A man can just be discerned leaning against the tramway pole. Actually the man is more visible in the photograph than he actually appeared to the observers, since glare from the nearest lamp reduced visibility for the observers, but was not registered by the camera. A piece of white paper was fixed against the fence, and the road rephotographed (see photograph 4).

The times of exposure, type of plates, time and temperature of development were the same for photographs 3 and 4. The improvement due to the whitening of the fence is apparent.

Photograph No. 5, which is of another part of the same road, also emphasises the importance of the background. The view is of a right-hand bend, and a car may be seen near the light source on the left-

Photograph 5.

hand side of the picture, silhouetted by slight contrast against a black background. A pedestrian about to step into the road is completely invisible. The spot where the pedestrian is standing is marked by a small white spot on the photograph.

The photograph over-emphasises the visibility of the car. This is another example of a danger spot arising from the ill-considered treatment of the background. The poor visibility here was accentuated by a glare source of high candle-power situated directly in the line of vision.

FIELDS.

The background here will in general be of very low reflection value and of such a nature that little use can be made of it. It would appear best under these conditions to direct the whole of the available flux on to the road surface.

SKY.

This is frequently the background where roads are undulating, often becoming the sole background at the crest of a rise or bridge. Probably the most important consideration under these conditions is the avoidance of glare. Engineers may well adopt, under these circumstances, some special means of eliminating glare such as the provision of "cut offs," opal shades, etc

VEHICLES.

The importance of this background is obviously dependent upon the traffic density; where this is high, the mode of lighting will be greatly influenced by this consideration. We have in this case to ensure contrast between vertical surfaces, and it seems reasonable to suppose that vertical illumination is the primary factor. Under these conditions a high flux and relatively close spacing are desirable.

Many factors intimately affecting contrast are not under the control of the public lighting engineer, and, indeed do not remain constant. A rigid contrast requirement is impossible, but much may be done by giving attention to the various considerations raised in this discussion. A survey of the thoroughfare by a competent lighting engineer is essential to a satisfactory installation; no installation can be completely planned on the drawing board.

Glare.

It is a matter of common experience that in general the levels of illumination under street lighting conditions are comparatively low, and, in consequence, any factor such as glare, which tends to reduce the sensitivity of the eye, is a factor of extreme importance.

It must be realised, however, that glare is a general term applied to many visual effects.* At the present stage of our knowledge it has become common to divide this phenomenon into two principal effects:—

(a) Discomfort glare.

(b) Disability glare.

(Other aspects of glare will be referred to later in this discussion.)

Discomfort glare may be considered broadly to result in an irritating effect which does not have the immediate result of reducing the sensitivity of the eye. Its effects, however, may be cumulative and finally result in impaired vision, eye strain, etc.

On the other hand, disability glare results in an immediate increase in the least perceptible contrasts the eye is able to appreciate at the given brightness level of the field. It is probable that a subject driving under adverse conditions of disability and/or discomfort glare will make unconsciously additional effort to see, which is likely to result, over a prolonged period, in undue fatigue

Luckiesh and Moss have endeavoured to measure the nervous muscular tension resulting from glare; but, as far as is known, this aspect has not been considered in any great detail in relation to street lighting.

As disability glare is the more direct and easier of assessment it is usual to assess the glare characteristic of a street lighting installation in terms of disability glare, but discomfort glare which is partly psychological in its effect must not be overlooked. It must be confessed, however, that the evaluation of glare for a street lighting installation is a matter of the greatest difficulty and, in consequence, no satisfactory clause has yet been drafted which can be readily applied under practical conditions. An attempt was made in the 1927 edition of the B.S.I. Street Lighting Specification, but subsequent work in this country on disability glare (notably by W. S. Stiles) has indicated that whilst the fundamental factors were to some extent appreciated, the clause was inadequate and led to results which were not wholly in accordance with experience. The attractiveness of the clause was in the simplicity of its application, since only a knowledge of the distribution curve for the fitting was necessary in order to apply the curves given in the specification to obtain a value for G, the glare figure.

It is necessary, however, in order to appreciate the limitations of the clause to examine the factors which were taken into account in establishing the curves. These were as follows:—

(1) The vertical illumination produced at the observer's eye due to the nearest lamp;

(2) The angle of separation between axis of vision and the glare source;

(3) The brightness of the background as computed in terms of the appropriate minimum horizontal illumination for the particular class.

* See Classification of Glare Phenomena—British Secretariat Report, I.C.I., 1935.

Further work since the publication of this specification has indicated that the glare clause based upon the above considerations was upon the right lines, but inadequate, for the following reasons:—

(a) The glare effect of the first lamp only was considered, but it has been shown that as much as 70% of the total glare effect may be due to more distant lamps.

(b) The evaluation of the brightness of the background in terms of minimum horizontal illumination is unsatisfactory, a low value for background brightness resulting in too high a value for G, and vice versa.

As a result of considerable laboratory work, an equation has been proposed of the form:—

$$G = 1 + \frac{K}{B}\left[\frac{E_1}{\theta^{1n}} + \frac{E_2}{\theta_2^{n}} + \ldots\ldots\ldots\ldots\right]$$

where E_1 and E_2 . . . are the vertical illuminations in foot-candles at the observer's eye due to the respective sources, θ and θ . . . are the angles in degrees between the line of sight and the respective sources, B is the brightness of the field expressed in candles per sq. ft., and K and n are constants found by experiment to have the values 11.0 and 2.1 respectively. It will be seen that when glare is absent, the value of $G = 1$. This formula has the merit of taking into account the vertical illumination due to the distant sources, but the difficulty in its application, as pointed out by Stiles, lies in deriving a true value for B. It was suggested by Stiles at the time of publication that the best that could be done to evaluate B was to assume an arbitrary diffuse reflection factor for the road of, say, 10%, and to couple this with a calculated value for the average horizontal illumination.

Since this work was done, instruments have been designed for, and observations made of, road surface brightness. In addition, work is in progress, both at home and on the Continent, to determine the value of road reflection coefficients, which, when complete, will be of great value in predicting the brightness of road surfaces under defined conditions.

The factors influencing disability glare may be conveniently separated into two parts:—

(a) Brightness of the field of view.

(b) A factor combining the vertical illumination at the observer's eye and the angle of separation.

Factor (a).

Modern work indicates that the brightness of the background in the immediate vicinity of an object is many times more important than the general level of brightness of the larger field. This fact would appear to simplify the assigning of an appropriate value for B in the glare formula, and for a stationary object seen against a background of known reflection characteristics, it is possible to estimate with fair precision the brightness of this restricted field. In practice, however, objects are not as a rule stationary, neither have the backgrounds equal and unvarying reflection properties, and hence the value of the glare estimated on these assumptions is unlikely to be an accurate prediction of the effects which will be experienced when the installation is erected.

Factor (b).

The vertical illumination at the observer's eyes is given by the well-known formula:—

$$E_v = \frac{I_\theta \sin^2\theta \cos\theta}{(H - \text{height of observer})^2}$$

where θ is the angle which the incident ray makes with the horizontal, and H is the mounting height. For practical purposes θ may be assumed to approximate to the angle of separation under consideration. The denominator of this expression is a constant in any given case, and, therefore, E_v may be considered as proportional to $I_\theta \sin^2\theta \cos\theta$. As has been stated elsewhere, the value of the disability glare produced by a constant vertical illumination at the observer's eye is inversely proportional to $\theta^{2.1}$. It is of interest to calculate the values of $\frac{\sin^2\theta \cos\theta}{\theta^{2.1}}$ for various values of θ.

The values are shown in the following table:—

θ	$\frac{\sin^2\theta \cos\theta}{\theta^{2.1}}$
1°	.000305
2°	.000284
3°	.000272
4°	.000264
5°	.000258
6°	.000252
7°	.000248
8°	.000243
9°	.000239
10°	.000236
12°	.000229
14°	.000223
16°	.000215
18°	.000210
20°	.000204

It will be seen that the values of $\frac{\sin^2\theta \cos\theta}{\theta^{2.1}}$ remain sensibly constant over a range $\theta = 5°$ $\theta = 15°$. If these values were constant over the whole range of angles, the candle-power the same for each angle, and the background brightness uniform, then an observer travelling along the road would experience a constant disability due to glare. In others words, under these conditions the contribution to the total glare from each source is the same, the actual value of the glare depending on the ratio of I_θ to B. In practice, sources having uniform distribution curves are seldom, if ever, employed, and maximum intensities usually occur at from 5° to 15° below the horizontal. Assuming for the moment a constant value for the brightness of the restricted field, it will be seen that the contribution to the total disability glare from the distant sources decreases as the maximum intensity makes greater angles with the horizontal. The assumption that the brightness of restricted field will remain constant under the above conditions is contrary to experience, since the reflection properties of certain backgrounds (more particularly road surfaces) decrease with decreasing angles of incidence with a consequent lowering of the background brightness. These two effects tend to neutralise one another, the ultimate result upon the glare figure being dependent upon the form of the distribution curve and the properties of the backgrounds. In two otherwise identical installations the absolute value of the glare figure will depend entirely upon the nature of the road surface. From considerations of the rate of increase of the reflection factors of the road surface for light at increasing angles of incidence, it has become common practice by some engineers to employ a high intensity beam near the horizontal to produce a high brightness of the road surface.

At this point it may be useful to refer to some personal observations made by Mr. Preston S. Millar in a communication sent to the British Secretariat Committee dealing with glare. These observations were printed in the Secretariat report recently presented to the I.C.I.

"Glare effects in reducing visibility in streets at night may be diminished:—

(a) By increasing the angular separation between the glaring source, and the centre of the field of view.

(b) By reducing the candle-power of the source in the direction of the observer.

(c) By reducing the brightness of the glare source in the direction of the observer.

(d) By rendering brighter the immediate environment of background of the glare source.

(e) By increasing the brightness of the general field of view.

Visibility in streets at night may be increased by providing more illumination and/or by increasing the brightness of the roadway. Or, it may be increased by diminishing the degrees of glare.

Numerical relationships, between these two means are not well established, but it is believed that the ratio of increased visibility accomplished through decrease in glare to that achieved by increased illumination intensity is relatively large."

Returning again to the previous considerations and referring to the statements quoted, it appears established that high-mounting heights are desirable in order to increase the angle of separation.

In designing an installation the engineer has a choice of two methods.

(a) High intensity beam at small angles with the horizontal.

(b) The maximum beam to be at say 15° or thereabout with the horizontal, with comparatively low candle-power values at the smaller angles. This second method can be carried still further, and a cut-off fitted down to say 5° below horizontal, or alternatively an opal cylinder fitted of similar dimensions to the cut-off.

In the first case reliance is placed upon the high brightness of the field off-setting the effect of high vertical illumination at the eye, in the second case the vertical illumination at the eye is reduced.

It must be frankly admitted that at the present state of our knowledge there is room for difference of opinion as to the relative effectiveness of the two methods in reducing disability glare.

The work done by Dr. Klein in Germany would seem to support the latter method. Dr. Klein indicates that both discernment and speed of recognition of the object viewed is prejudiced if high intensity beams are used at angles above about 15° with the horizontal. One of the present authors was much impressed during a recent visit to Germany to see that opal cylinders, etc., were much employed even in the modern installations to diminish the candle-power at angles near the horizontal. Without wishing to prejudge the results of any work that may be under consideration, the authors, so far as their experience and knowledge of the subject enables them to form an opinion, favour the avoidance of high intensity beams at angles near the horizontal, and advance the following observations in support of their opinion.

The absolute value of the brightness of the road surface for any given installation must depend upon the characteristics of the road surface.

The engineer cannot insist that the road surface most suited to the projected installation is selected.

Moreover, the characteristics of the road surface change with usage, weather conditions, etc., and several dressings not necessarily having the same optical properties may be applied during the life of the installation. It follows that if the major reliance is placed upon securing a given range of field brightnesses, the engineer is relying upon a factor over which he has not complete control.

On the other hand the character of the distribution is under the control, and there can be little doubt that if an opal cylinder or the like is used, both disability and discomfort glare are reduced to a minimum.

Some criticism may be made of the formula for estimating glare in that it implies that equal increments of glare are accompanied by correspondingly equal decrements of visibility. Recent work suggests that this is not true; but the formula as it stands is probably near enough to the truth to indicate the nature of the factors involved and the manner in which they operate for a stationary or slow-moving observer.

Much work of a fundamental nature must be done before the public lighting engineer is able to give a figure for an installation which will be a true index of the disability and discomfort occasioned by glare sources.

Space will not permit of detailed consideration of the various aspects of glare and their effects upon the visibility, but the classification given in the Secretariat report to the I.C.I. is suggestive, and merits study. In this classification the effects of glare are classified under the following headings:—

A. Sensation of discomfort, distraction or strain.
B. Measurable reduction in visual capacities, or in the efficiency of performance of work involving vision in some degree.
C. Modification in the involuntary physiological reaction to the situation.
D. After image and irradiation effects.
E. Pathological after effects.

There can be little doubt that some, if not all, of these effects are operative under street lighting conditions, and will need to be assessed and allowed for before the glare problem may be considered as solved.

In addition, as the classification suggests, the line of vision is not always fixed. Indeed, in street lighting problems the direction of vision may be assumed to wander without restraint over the whole or larger part of the field of view. Objects too are seen by foveal and extra foveal vision. Moving objects have to be seen by subjects who are themselves moving. All these and many other factors are of importance in considering the promotion of visibility by public lighting.

Kinetic Conditions.

Under practical conditions of street lighting the light stimulus received promotes a psychological response which finally results in some physiological action. It follows that factors which are subjective are of importance in street lighting practice.

Moreover, since moving objects are frequently to be observed by subjects not at rest the kinetic condition is of the utmost importance

This is a sphere of work involving the psychologist, the physiologist and the illuminating engineer, and there can be little doubt that the safe lighting of our thoroughfares requires co-operation between workers in all three fields.

The necessity of co-operation between the physiologist and the lighting engineer will be apparent from what has already been said in regard to glare, and, indeed, it is accepted in the recognised definition of luminous radiation. Moreover, little imagination is required to appreciate that psychology plays a not unimportant part in the lighting problem.

To make such a statement is simple, and the truth of the statement will be generally accepted, but difficulty arises immediately an attempt is made to formulate some method of test which will indicate to the street lighting engineer the correct technique to satisfy this trinity of requirements.

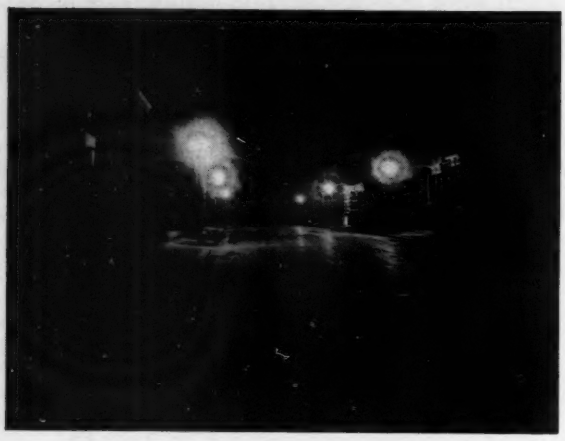
Much of the work carried out by the street lighting engineer has been under static conditions, and without wishing to appear critical of these efforts this fact alone, in the writers' opinion, may have led to incorrect deductions for lighting requirements.

Without desiring to labour the question of physiological response, and purely as illustrative,

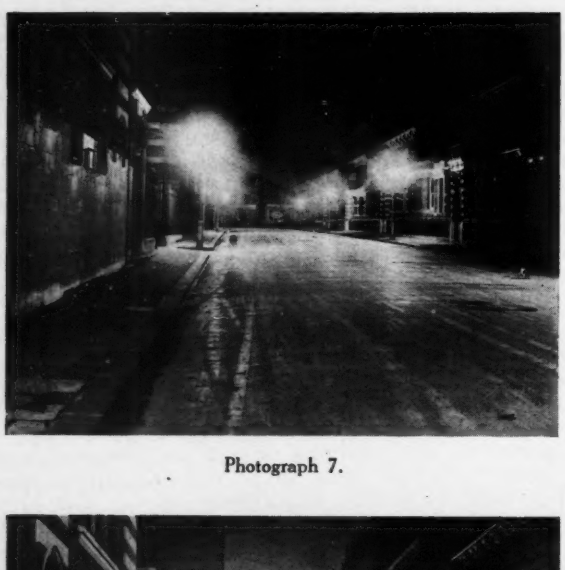
mention may be made of the deductions that are sometimes made as to the merits of a street lighting installation from photographs taken under static and uncontrolled conditions.

Photographs 6, 7, and 8 are of the same thoroughfare taken on plates from the same packet, developed and printed under precisely similar conditions. The ratio of the times of exposures were as follows:—

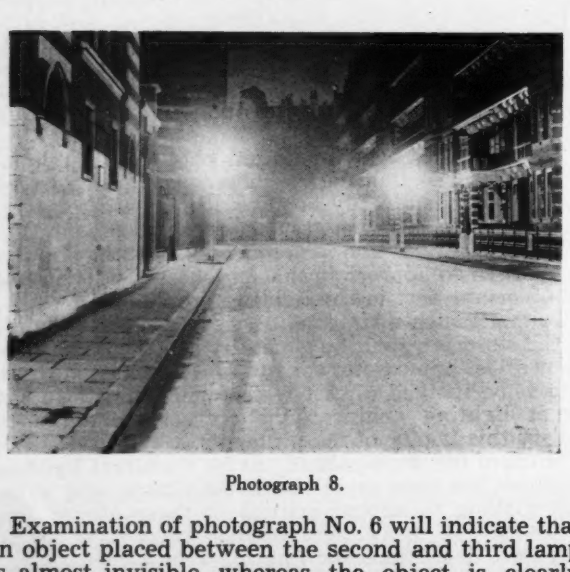
Photograph No. 6 — exposure time 1.
Photograph No. 7 — exposure time 3.
Photograph No. 8 — exposure time 9.



Photograph 6.



Photograph 7.



Photograph 8.

Examination of photograph No. 6 will indicate that an object placed between the second and third lamp is almost invisible, whereas the object is clearly visible in photographs Nos. 7 and 8

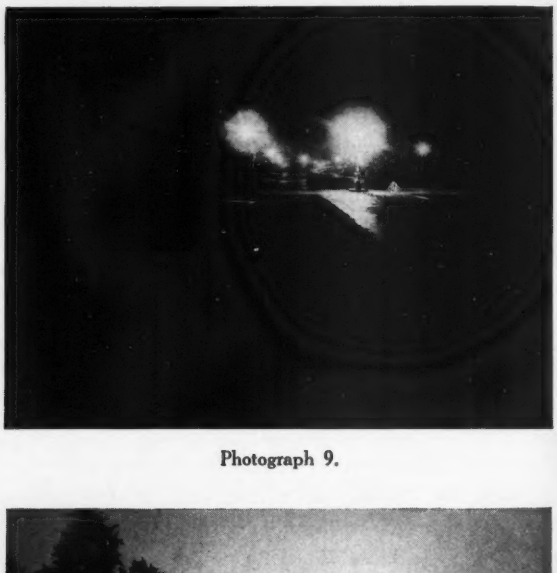
Moreover, the brightness of the road appears to be very good in the case of the negatives with prolonged exposure, and very inferior in the other cases. In certain of these photographs the name on the facia is clearly visible, but in the evening this name was not visible to those in the street at the position of the camera, again mainly on account of glare.

Photographs Nos. 1, 9, and 10 were taken under similar conditions. The exposures were as follows:—

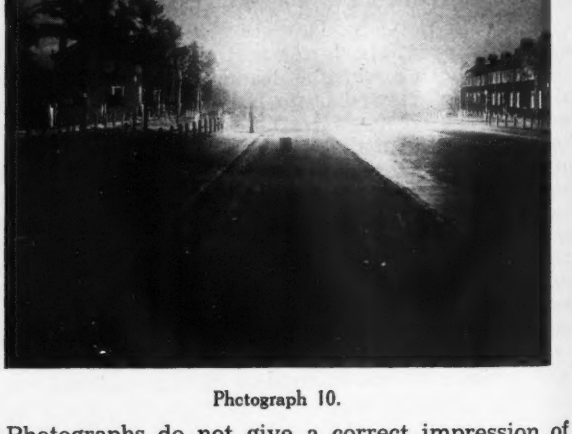
Photograph No. 1 — 15 min.
Photograph No. 9 — 5 min.
Photograph No. 10 — 45 min.

Unfortunately day was beginning to dawn when No. 1 was taken and, in consequence, the sky light is over emphasised

Again, an object clearly visible in Nos. 1 and 10 is entirely invisible in No. 9.



Photograph 9.



Photograph 10.

Photographs do not give a correct impression of what is seen unless they are taken under scientifically controlled conditions, since the chemical effect of light upon the emulsion is cumulative, whereas, once eye adaptation has occurred, no such cumulative effect is experienced by the eye.

Further, the data usually given by the illuminating engineer may fail to convey a true appreciation of the merits of the lighting of a street unless accompanied by some form of test which takes into account the physiological and psychological response of the subject under the actual conditions experienced in the street.

Photograph No. 11 is included, as it may be of interest. This print is faked by shading the negative during the printing process. The fake may not be obvious to the inexperienced eye, but the authors

Photograph 11.

have seen photographs used in catalogues, etc., which were obviously faked in a similar manner. Engineers of standing will deprecate such practices.

Reference has already been made to the difficulty of outlining any test or tests which can be made under kinetic conditions and which will take into account the factors of response previously referred to.

One of the authors was privileged to discuss this matter with Dr. Halbertsma during the I.C.I. Congress at Berlin, and as a result of this discussion it was considered that a test carried out on the following lines might be of interest.

A route should be selected along which were a series of street lighting installations differing in character and intensity. Each installation should be of appreciable length, say, not less than 1 mile or, preferably, 1½ miles in length. A number of motorists should be requested to drive over the route in various types of vehicles. It is of importance that the drivers should be unaware that any tests were being made, so that abnormal conditions are not introduced. Each car to be fitted with a recording device to indicate the speed, etc., attained and maintained on any part of the route.

It is possible that an analysis of a very large number of these charts upon a statistical basis would indicate that the majority of the drivers found it necessary to reduce speed or take especial precautions at certain parts of the route. A very careful examination could be made of these interesting parts of the route, and a reason or reasons could be assigned for the additional care exercised.

It is easy to suggest a number of tests of a similar character which could be tried: for instance, records could be made of the conditions under which the majority of drivers found it expedient to use headlights over the prescribed route. If these, or similar, tests were carried out on a fairly ambitious scale, it is possible that information would be obtained that would reveal the weaknesses of the installations examined and enable broad principles to be established which, if applied, would be conducive to greater safety on the roads.

A similar set of experiments could be made by pedestrians so that their requirements under practical conditions were also considered. It is apparent that such experiments must be carried out under controlled conditions, and that the results would require interpreting by those skilled in statistical analysis.

B.S.I. Street Lighting Specification.

This specification has been subjected to searching criticism, and there can be little doubt that many amendments and revisions will be necessary before an entirely satisfactory specification is available.

It is well to remember, however, that a measure of agreement between all interested parties upon a basis of established good practice must always be secured before a British Standard Specification can be issued or amended; on the other hand, it is freely conceded that a specification lagging behind new developments is an encumbrance which is not to be tolerated.

Ignoring ignorant and ill-informed criticisms of the street lighting specification as unworthy of serious comment, it must be admitted freely that many whose opinions are entitled to the utmost respect feel, and feel very keenly, that the specification in its present form operates unfairly against new developments of undoubted interest and importance. On the other hand, there are others who do not share this view, and believe that all these new developments can find equitable expression within the present specification.

A street lighting installation is erected to promote safety for the motorist and pedestrian alike during hours of artificial lighting, and the safety of both these road users presupposes their ability to see with reasonable ease. The inherent difficulty in drafting a street lighting specification is that many of the factors affecting visibility in the streets are imperfectly understood and arising out of this, if not in consequence of it, no scale for visibility exists by which the visibility requirement for the installation can be specified.

This fact, as has been pointed out before in this paper, necessitates the adoption of criteria which in practice are likely to provide an index most in accordance with what practical experience dictates as desirable. There can be little doubt that factors other than light flux, distribution of flux and arrangement of sources are of importance in securing visibility, and that over some of these other requirements the lighting engineer has little, if any, control.

It is well to remember that the B.S.I. Specification for street lighting is, after all, a *specification* often forming the basis of contract obligation, and it is unreal to seek to impose requirements assuming a control which the lighting engineer does not possess.

A further criticism of the specification which has been urged repeatedly is that it is too complicated and, in consequence, little used.

Another criticism of the specification is that it is possible for two or more installations to comply with the requirements for a given class, and yet differ widely in many respects from each other; within limits the authors do not agree that this is of necessity undesirable.

A lighting code may be so general as to become valueless and allow very inferior installations to comply with the requirements; on the other hand a code may be so specific that an installation judged to be of equal merit to another may be ruled out simply because the code is so specific.

We believe the B.S.I. Specification, whilst permitting of differing types of installation, satisfying the requirements, is in general sufficiently specific as to rule out installations which are obviously inferior as judged by present day standards.

So much has been said in criticism of the B.S.I. Specification that there is danger of losing sight of its undoubted merits. It may be useful to state briefly the case for the specification as the authors see it.

(1).—A review of the various national codes establishes beyond question that the B.S.I. Specification is the most complete and ambitious statement of the requirements for street lighting yet available. So far as the authors have been able to discover, no other national code has yet formed the basis of a specification of national standing.

It is possible that the criticism of complication arises out of the endeavour to make the specification thorough and sufficiently specific.

(2).—The criteria adopted, which must not be divorced from the other equally important requirements to be referred to later, is that of minimum

illumination on the highway. It is the function of the street lighting engineer to provide light and distribute it in a manner best suited to the requirements of the particular thoroughfare.

A minimum illumination requirement, coupled with a recommended height, and the limiting spacing height ratio permissible for the class does ensure that a minimum flux of light is available to illuminate the highway.

It can be argued, and argued truly, that it is the flux reflected from the appropriate surfaces which is of importance. While it is agreed that the lighting engineer should co-operate in every possible way with the road engineer and others who may be concerned, it cannot be said that the control of the nature of the surfaces which have to be illuminated is with the lighting engineer.

Therefore, for the purpose of a specification, it appears to the authors that the lighting engineers' obligation must end with providing the quantity of light required, and distributing the light in accordance with the requirements of the specification. Few will doubt that there is a real relationship between the quantity of light provided and the ease with which one sees, and in consequence, although it is freely admitted that other factors have an important bearing upon visibility, there appears to be good reason in adopting minimum horizontal illumination, coupled with the other requirements in the specification as a suitable criterion for specifying street lighting. In general the authors believe that the more light provided (if distributed and arranged to satisfy the requirements of the specification) the greater the visibility in the street, although it is true that in a small minority of cases this generalisation is not completely satisfied. As far as we are aware, no one has suggested that surface brightness should be substituted in the specification for minimum illumination. If such a criterion were adopted, the latitude permissible under testing conditions would have to be considerably wider than that necessary for minimum illumination requirements; there would always be the necessity of determining whether a low brightness was due to a low value for the incident light, or a reduction in the reflection coefficient of the surface upon which the light was incident.

(3).—The specification prescribes minimum mounting heights, maximum spacing height ratios, and Clause 17 (which deals with variations in rated illumination at test points) is drawn in a way calculated to discourage high diversity of illumination. It would appear, therefore, that the specification goes as far as agreement at the moment will permit to define the conditions tending to minimise glare effects. In addition, Clause 22 gives sound advice by suggesting glare can be minimised by decreasing the spacing and increasing the height of the light source. It is clear from a previous section of this paper that the authors are in favour of limiting the permissible candle-powers at angles near the horizontal, but this is not an agreed remedy, and, therefore, cannot be included in the specification until lighting engineers are agreed as to the efficacy of the principle.

(4).—One of the most valuable aspects of the specification is undoubtedly to be found in the information to be provided with the tender. This requirement appears to the authors to take for granted that street lighting should be under the charge of a competent engineer, otherwise it is difficult to see what legitimate use can be made of the information to be supplied. The information in the hands of a competent engineer thoroughly familiar with the street to be lighted is of the utmost value.

In addition, the information to be supplied with the tender ensures that the engineer designing the installation shall be provided with all the necessary data.

(5).—The specification is flexible enough to deal with difficult cases. To illustrate this point, Clause 16 may be referred to:—

> "In other cases and where the symmetry of an installation is to be materially disturbed to make provision for lighting the entrance of side streets, or other reasons, the positions of any test points shall be those at which the illumination due to the light source under consideration would be a minimum, and *these positions shall be agreed* by the parties concerned."

(6).—The specification provides for a testing clause, which can be applied to ascertain if the installation as designed has realised the design values, or may be used to ensure the installation is being reasonably maintained. It is impossible, in the authors' opinion, to over-stress the importance of good maintenance in street lighting installations.

In conclusion, we desire to thank the Governor and Court of Directors of the Gas Light and Coke Company for permission to publish this paper, and for the facilities provided during its preparation. We should also like to acknowledge the assistance given us by Mr. D. G. Winslow in the preparation of the appendix.

APPENDIX

THE CONSTRUCTION AND USE OF ISO-FOOT CANDLE DIAGRAMS.

The horizontal illumination at any point on the road may be determined from the well-known formula

$$E_h = \frac{I_{\theta\alpha} \cos^3\theta}{H^2} \quad \ldots\ldots\ldots(1)$$

Where E_h = horizontal illumination at the point.
θ = angle of incidence, being the angle between downward vertical through lamp and a line joining the point to the lamp;
$I_{\theta\alpha}$ = candlepower of lamp at vertical angle θ and azimuth angle α.
H = mounting height of the lamp in feet.

The corresponding horizontal distance of the point from the lamp is given by

$$d = H \tan\theta \quad \ldots\ldots\ldots(2)$$

Expressions (1) and (2) suffice to calculate from any isocandle diagram the distribution of illumination on the road in any specific case. It frequently happens, however, that in practice the same lamp will be used from time to time at different mounting heights, each occasion necessitating the preparation of a fresh iso-footcandle diagram.

In the present method one diagram is made to serve for all mounting heights by the following artifice. In the expressions (1) and (2), H is put equal to unity in the initial stages of constructing the iso-footcandle diagram so that the illumination values are in arbitrary units which can later be converted to footcandles by dividing by H^2 when this has been chosen. At the same time the scale of distance is made to read directly in feet by multiplying by H.

The following example will make the method clear.

Drawing the Iso-footcandle Diagram for One Lamp.

Figure 1 shows a series of concentric circles with centre at 'a' and radii 1", 2", 3" . . . . . with radial lines drawn every 10°. These lines must be supposed to be drawn on the road surface and the lamp to be vertically above 'a' at a height equal to the radius of circle 'c.'

Light from the lamp will therefore be incident at all points on this circle at an angle of 45°. Similarly, there is a fixed angle of incidence θ, which may be calculated, corresponding to each of the other circles. These values are set out in Table I together with the values of $\text{Cos}^3\theta$

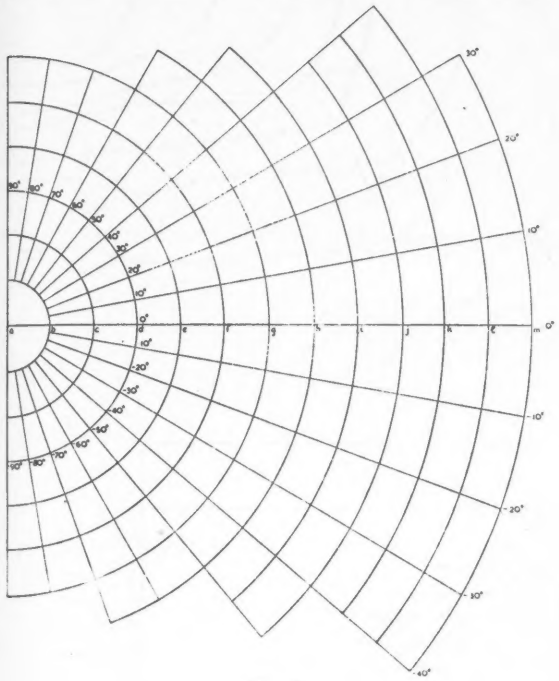


Fig. 1.

Circle	θ	$\text{Cos}^3\theta$
a	0°	1
b	26°36′	0.714
c	45°0′	0.354
d	56°18′	0.171
e	63°24′	0.0897
f	68°12′	0.0512
g	71°36′	0.0315
h	74°0′	0.0210
i	76°0′	0.0142
j	77°30′	0.0101
k	78°42′	0.00753
m	80°36′	0.00432

These concentric circles may be projected on to the sinusoidal diagram as a series of straight lines drawn parallel to the lines of latitude. The axially drawn lines will similarly on projection coincide with the lines of longitude, the 0° line of figure 1 falling along the centre line of the projection. This is shown in figure 2 where the dotted lines are lettered to correspond with the circles of figure 1. If, now, an isocandle diagram on the same projection (figure 3) is superimposed on figure 2, it is possible to read off the candlepower in the direction of each of the "junctions" (the intersections of radii and circles) of figure 1, and, by multiplying the candlepower by the appropriate value of $\text{Cos}^3\theta$ convert it to a number proportional to the horizontal illumination at the point. The values so obtained are then plotted in their relative positions on a blank sheet of transparent paper placed over figure 1, as in figure 4.

For example, suppose it is required to calculate the illumination at the junction of the radial line marked +20° with the circle c (figure 1). The position of this point in the sinusoidal projection is given by figure 2 and the candle power in that direction is found to be approximately 400 on superimposing figure 3. From Table I., for all points on circle c, $\text{Cos}^3\theta = 0.354$. Whence $I\ \text{Cos}^3\theta = 400 \times 0.354 = 141.6$. This value is accordingly entered against the chosen point on the blank sheet.

The method is repeated for every other junction in figure 1. Contour lines of suitable values are then drawn in by interpolation between the points obtained, as in figure 4.

The final diagram obtained will be similar to figure 5(a) with contours drawn for round numbers. It is not, in general, found necessary to convert these to footcandles at the present stage, but this may be done in any specific case. Suppose, for example, that the lamp is to be mounted in one instance at 20′. Then, as explained at the beginning of this note, if the numbers on the contours are divided by H^2 (in this case 400) the contours will denote actual footcandles. Further, since the radius of circle c was made equal to one mounting

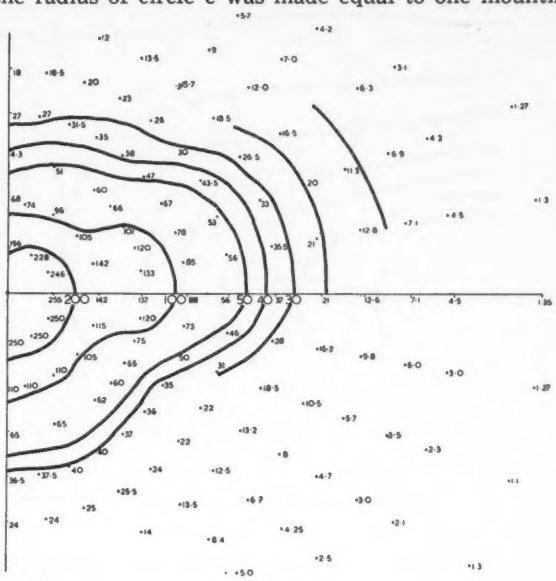


Fig. 4.

height, the distance ac, 2″ in length, now represents 20′; that is to say, the linear scale of the diagram becomes

$$1'' = \frac{H}{2} = 10'.$$

If the mounting height in the next instance should be 25′ then the contours numbers must be divided by 625 to read footcandles and the scale of the diagram becomes 1″ = 12′ 6″.

Drawing the Iso-Footcandle Diagram for an Installation.

The method of applying the distribution diagram obtained above for the single lamp can best be explained by taking a concrete example. Suppose it is required to determine the spacing, and construct the final iso-footcandle diagram for, an installation satisfying Class E of the B.S.I. Specification (minimum horizontal illumination = 0.1 f.c.) utilising the lamp whose iso-candle diagram is shown in figure 3. The road width is thirty feet and the mounting height in this instance is to be 20′. Staggered formation is to be used with the lamps mounted directly over the kerb.

Since the mounting height is 20′ the scale of distance, as explained above, is given by $1'' = \frac{H'}{2} = 10'$. The road is therefore represented as in figure 5(c) by two parallel lines drawn 3″ apart. At some convenient point on one of these lines figure 5(a) is fixed and an inverted copy of 5(a) (figure 5(b)) is placed over it as in the accompanying transparencies. As figure 5(b) is moved along its kerb line the contours of the two diagrams will intersect, the resultant illumination at any point being the sum of the values of the contours passing through that point.

Now, since the mounting height in this case is 20′, $H^2 = 400$ and therefore a minimum value of 40 arbitrary units must be obtained on figure 5 to ensure 0.1 f.c. This will be assured when the two 20 contours overlap just outside the boundary of the road. Similarly, the two 10 contours could be made to overlap to produce a minimum of 20 units or 0.05 f.c. for Class F., etc. The required spacing is then given by measuring the distance between lamps on the scale derived above. In the example given the distance between lamps parallel to the kerb is 13.3″, which is equal to 133′ on the road.

The final iso-footcandle diagram for the span is then obtained by adding the value of the overlapping contours at a number of points and dividing at the same time by H^2. Figure 6 shows such a diagram obtained under the given conditions with contours marked in footcandles.

The same diagrams 5(a) and 5(b) can be used for any other mounting height provided the contour numbers are divided by the appropriate H^2 and the scale of dis-

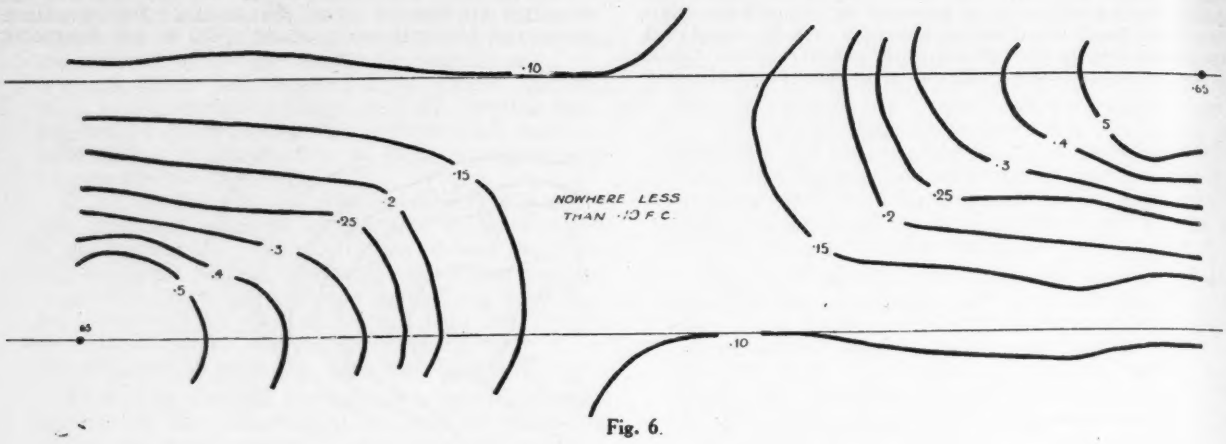


Fig. 6.

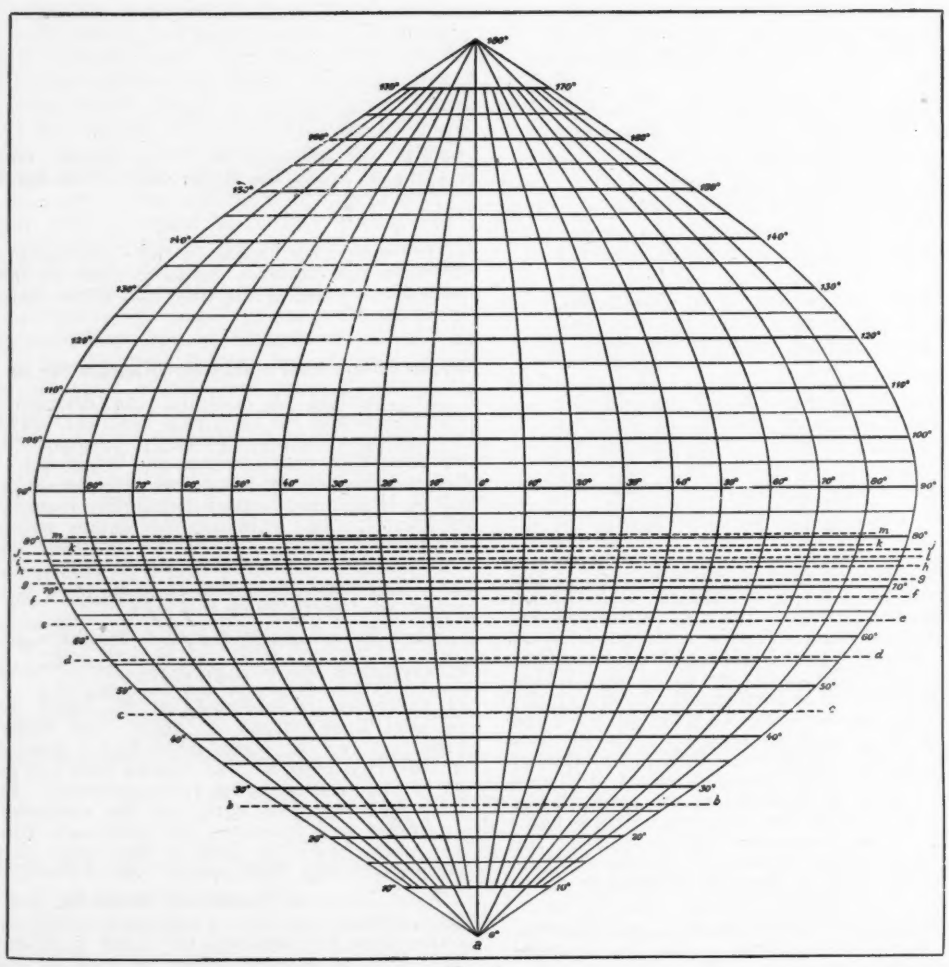


Fig. 2.

Fig. 5c.

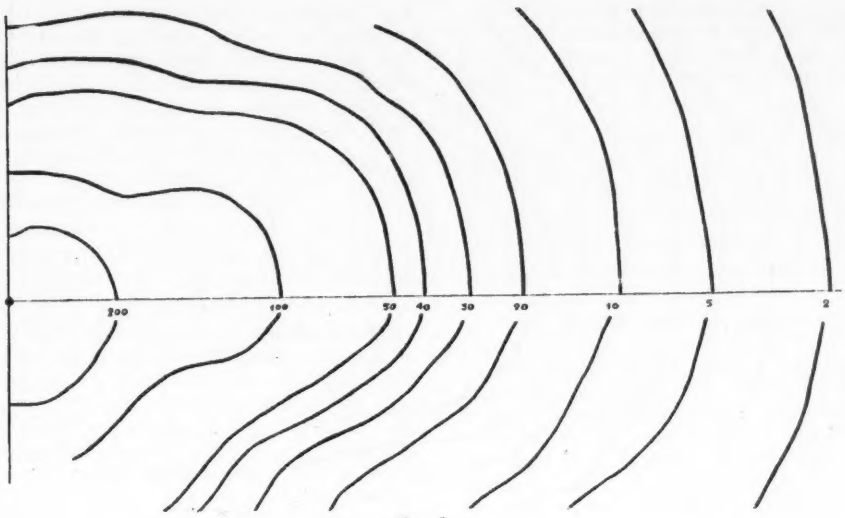


Fig. 5a.

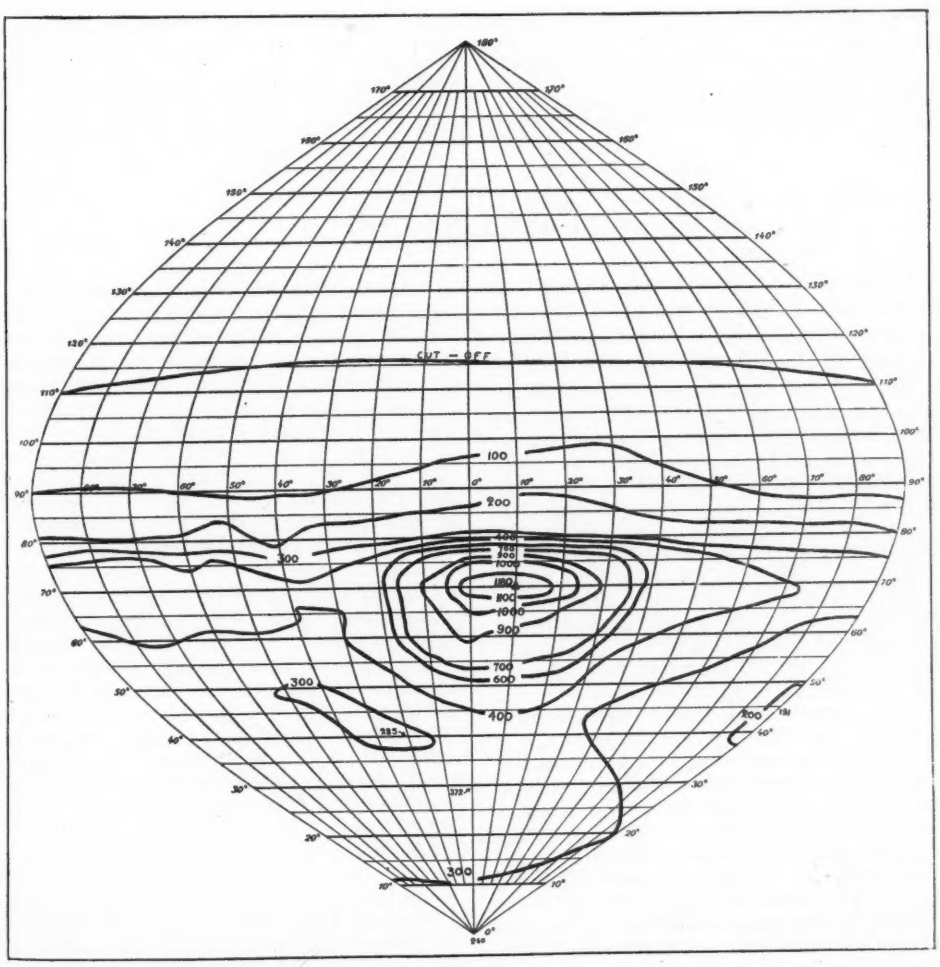


Fig. 3.

tances altered to read 1″=H/2 feet. Thus once the relative distribution of illumination has been obtained as in figure 5(a) any number of final distributions similar to figure 6 may readily and quickly be obtained whatever the details of the mounting, since the applications to overhang and centre suspension are obvious.

The necessity of using these diagrams in planning an installation rather than relying solely upon calculated mid-span point illuminations is well illustrated in the following case. Suppose that, other details remaining the same, Class D (minimum illumination 0.2 f.c.) had been required instead of Class E in the example worked out above. By sliding figure 5(b) over figure 5(a) it will be found that at the mid-span point a value of 80 units, corresponding to 0.2 f.c., can be obtained with a spacing of 100 feet. Further examination of the figures will show, however, that at places on the kerb between this point and the point opposite the lamp the illumina-

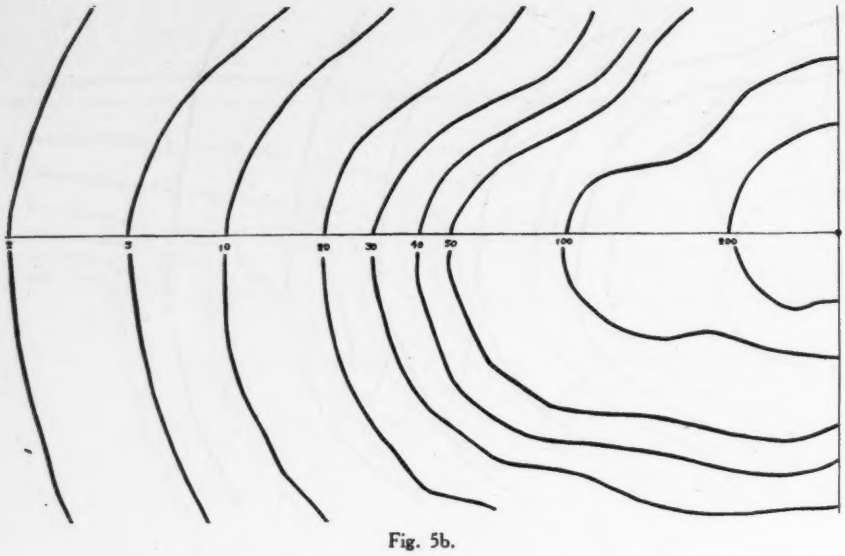


Fig. 5b.

[N.B.—In presenting this contribution at the Conference the authors arranged for Figs, 2 and 3, and 5a, 5b and 5c to be printed on transparent paper so that these figures could be superimposed in the manner indicated in the paper.]

tion is less than at the mid-span point. Such an installation would still fall within the lower class of the Specification. Not until the spacing is decreased to 60′ does the installation satisfy the requirements of Class D in that at no point does the illumination fall below 0.2 f.c. The point of lowest illumination which under the terms of the Specification now becomes the test point then lies not at a point equidistant from the lamps but at a point opposite the lamp. This state of affairs often arises when the directional properties of a lamp are over-developed, or, as in the present case, when the lamp used is not large enough for the class of installation.

DISCUSSION

Mr. PERCY GOOD (British Standards Institution) remarked that the view held by some motorists that the best conditions of visibility were secured when there was no street lighting at all, might be true in isolated cases but not for the conditions prevailing in city and suburban areas. He was glad the authors had joined issue with those critics of the standard specification who said that, because visibility was necessary but was not specified directly, therefore this was a bad specification. Only few specifications could actually specify the thing which was really required; the majority achieved success by specifying some relevant matters. The fact that visibility could not be easily defined was not in itself a reasonable criticism of the specification. The way in which the authors had approached this problem was commendable. Mr. Good said the film that had been shown was extremely interesting, and demonstrated that a reasonably light road surface had considerable advantages. When Mr. Smith was able to take a similar film at night attention might be given to the angle at which the camera was pointing. The camera seemed to point a little too far ahead as compared with the point of view obtained when driving in busy traffic, particularly at night. Possibly some measure of the average angle of observation of vehicle drivers could be adopted. Incidentally, danger to other users of the road might arise in the case of car drivers whose view was impeded by the fact that they were shorter than the average. Cyclists on the road might, when at close quarters, be obscured by the bonnet of a large car. In conclusion. Mr. Good emphasised that the specification represented the collective views of a number of people after taking into account many criticisms. It was thus in the nature of a compromise, and it must be regarded as a tool or implement, not as, so to speak, the Ten Commandments. It was not intended to stop progress and should not do so if properly used. Naturally, any tool, however good it might be, would quickly fail to function in the hands of anyone who did not understand how to use it.

Mr. C. HARPER (Barking) said that it would be useful to have comparative data on concrete, in view of the good light-reflecting value of such a surface, as well as other road materials. He also commented on the paragraph in the paper referring to co-operation with municipal engineers in connection with the provision of backgrounds of higher reflecting value. It seemed to have been overlooked that throughout the country the municipal engineer, in most cases, was the official responsible for public lighting—a condition specified in the Public Health Act of 1875 and not modified by subsequent legislation.

Mr. E. L. DAMANT (General Electric Co., Ltd.), in suggesting some modifications in the headings of Table I., remarked that in over 90 per cent. of the cases at least some portion of the object was visible against the roadway. So far as background was concerned, there was not much chance of making alterations either in existing roadway surfaces or surfaces of adjacent houses. He suggested that possibly measurements on a small vertical surface, instead of a horizontal one, might have advantages. They would meet the views of those who attached importance to illumination of vertical surfaces and would also afford a closer relation to the resultant brightness on the road than did illumination on a horizontal test plate. They would thus furnish a sort of compromise between the two schools of thought.

Dr. S. ENGLISH (London) congratulated the gas industry on the presentation of two such valuable papers as the present one and that read by Mr. Chandler and Mr. Smith on the preceding day. Mr. Smith had provided a masterly survey of modern views on street lighting. There was a tendency to speak of an increased candlepower near the horizontal as an absolute essential for good road lighting. This seemed to him an over-statement. In the case of long lengths of arterial roads, with only gent'e curves, with much vehicular traffic, and with little pedestrian traffic, it was doubtless desirable to have

the maximum only slightly below the horizontal, and thus to obtain the so-called high surface brightness. But in urban and suburban areas, where there was much more pedestrian traffic and roads had many turns, a different method should be adopted. In such cases a maximum candlepower distinctly lower than the horizontal was preferable. If these two distinct types of road were kept in mind there would be less apparent differences in the point of view.

Mr. D. G. SANDEMAN (Edinburgh), whilst appreciating the difficulty in reconciling so many conflicting interests experienced by those responsible for the British Standard Specification, said that it had evident limitations. The correct positions of public lamps were much more important in practice than the shape of the polar curve of light distribution. He thought that surface brightness could be made the basis of a specification—possibly by laying down a standard surface 300 or 400 yards long, where lighting fittings could be tested. Glare, which was inversely proportional to the height of mounting, should also be included.

Mr. G. H. WILSON (Research Laboratories, General Electric Co., Ltd.) complimented the authors on their statesmanlike survey of the factors involved in street lighting. Although the factors involved in visibility were many and complex, the solution of the problem was not insuperable. He was confident that, notwithstanding these difficulties, Mr. Smith and Mr. Sawyer could plan a perfectly good street lighting installation which would satisfy the most critical—and he personally believed that he could do the same! They had seen on the previous evening some excellent examples of public lighting, and there was no need to despair because all the factors affecting visibility, which the authors had so ably summarised, had not been fully studied. Nevertheless he hoped that more information on them would soon be forthcoming. It was doubtless possible to state the conditions of flux, mounting height and spacing which would result in a good installation, though it might be more difficult to define them in the case of an installation which was only just adequate. Whilst it might be agreed that the street surface was not the all-important background, it was, nevertheless, true that information on this point would generally give a good idea of the performance of the installation. In his experience when the road brightness was high and reasonably uniform other backgrounds would, in ordinary circumstances, be adequately bright. Moreover, as Mr. Smith had mentioned, although only 30 per cent. of an object might be seen against the street surface, that 30 per cent. might be more valuable than the figure would suggest—because the street was so very much brighter than the other backgrounds.

In conclusion, Mr. Wilson said that a simple technique for producing street lighting photographs which could safely be used for comparative purposes had recently been worked out, and a paper was to be read on this subject before the Illuminating Engineering Society by Mr. Ralph Hopkinson.

Mr. J. S. Dow remarked on the general impression that with the attainment of high and uniform brightness on the street surface, the best possible condition for visibility was automatically secured. Was it conceivable, however, that with artificial illuminants an excessive brightness, forming an actual drawback to visibility because of the glare, could be produced? It was a fact that the effect of brilliant sunlight reflected direct into the eyes from a highly polished roadway might be dazzling to a degree, notwithstanding the relatively high brightness of the surroundings. In the sombre surroundings of an artificially lighted street it did seem possible that reflected light from a street surface might result in glare. He recalled, some years ago, a letter from a public lighting engineer abroad who stated that when the road surface was wet and shiny, centrally suspended lamps had proved objectionable in this respect, though satisfactory enough with a dry road.

Mr. J. H. BURMAN (North Middlesex Gas Co.) agreed in regard to the difficulty of controlling the light-reflecting qualities of backgrounds. It might, however, be easier to control that of the objects themselves, as was illustrated by the expedient of the Girl Guide captain who conceived the idea of her girls wearing a white towel or sewing small reflectors on to their dresses as a precaution when using country roads during the darkness! It was noticeable how certain buses which were encircled by a white band stood out at night; the white sleeve worn by policemen, white painted vans and tradesmen's cyclists wearing white were likewise easily seen. The desirability of measuring illumination on a horizontal surface had been questioned, and one speaker had recommended a vertical surface. He himself had another idea, namely, that the light should be received and measured on a spherical surface of such a character that light coming from all directions was recorded. It should not be difficult to evolve an instrument using such a surface in conjunction with a photo-electric cell.

Mr. J. M. WALDRAM (Research Laboratories of the General Electric Co.), remarked that the paper might be described as a masterly summary of our ignorance on this subject; it was the more welcome because there was a danger of concentrating on the things that were known and ignoring those that were not. There were, however, some things that were definitely known in regard to visibility, and should not be overlooked. The evident fact that anything visible was only seen by reason of its brightness, i.e., the light coming from it, was not always appreciated. The desirable value of brightness and its distribution were, of course, matters for argument and discussion. The film had been most interesting, and he hoped that it would soon be possible to take a similar one by artificial light. He was rather puzzled by a statement in the paper that no part of the outlines of 14 per cent. of people standing in the road was seen against this surface. It might happen in the case of a hump-backed ridge, but, even so, he would not have expected so large a proportion. He was also rather surprised that in the case of people standing on the kerb, 12 per cent. of the outline was seen against other backgrounds.

Mr. Smith, interposing, explained that this was due to the curve of the road.

Mr. Waldram suggested that in order to get a true figure of merit both the amount of an object seen against a background and the degree of contrast should be considered. Those who had concentrated attention on road surfaces had not overlooked the value of other possible backgrounds, but the latter were less easy to control than the road surface. He mentioned a road near Berlin which was practically devoid of effective background with the exception of the road-surface; yet the visibility had been excellent. In conclusion, Mr. Waldram said that glare had always been the bogy of street lighting. Its dangers were often emphasised without its nature being fully understood. In this connection he referred to a specific case which he illustrated by means of a lantern slide. The work of Stiles and Harrison on glare had shown that its effect could be replaced by a sort of veiling brightness over the whole view. In the case mentioned, a reasonably designed installation, but sometimes described as glaring, the veiling brightness factor, which could be readily calculated, came out to 1.2, i.e., the veiling brightness was 15 to 20 per cent. of the road bright-

ness. This seemed to show that the effect was not so serious as people sometimes imagined.

Mr. C. A. MASTERMAN (Gas, Light and Coke Co.), referring to Mr. Wilson's remarks, expressed the hope that very soon photographs illustrating street lighting might be the subject of a specification which would ensure that they gave a correct impression of what was actually visible. He wished also to support the author's defence of the British Standard Specification for street lighting. The more he had studied that specification, and incidentally tried to improve it, the more impressed he had been by the manner in which it had been drafted. He was amongst those who felt that over-concentration on road-brightness was liable to involve introduction of glare—for the two conditions were necessarily closely associated. Further, he did not think that the basis of the present specification could be shifted on to something so uncertain as brightness. The specification admittedly should not be regarded as final and complete. It was primarily a basis of co-operation between buyer and seller. If it was used as a bone of contention amongst competitors—then, naturally, the bone suffered in the ensuing struggle! Therefore, he urged that the specification should be used on the former basis in a spirit of co-operation and in the interests of efficient street lighting.

Mr. E. STROUD (London) remarked that the chief difficulty that had been experienced in using the specification was a tendency to over-emphasise certain features in it and thus to cloud the issue and make the specification appear more intricate than it really was. The fundamental difficulty in street lighting was simply that there was not sufficient light—hence the effort to make use of specular reflection and increase the brightness of the roadway in any way possible. The Committee concerned with the Standard Specification had studied very carefully methods of defining the illumination, and it might be assumed that their adoption of horizontal illumination had not been taken without full consideration of alternative methods. In conclusion, Mr. Stroud remarked that little had been said about the iso-lux diagrams contained in the appendix of the paper. The methods there outlined by the authors should prove very useful in facilitating quick design and aiding what was becoming a rather complex procedure.

Mr. F. C. SMITH, replying to the discussion, agreed with Mr. Good in regard to the position of the camera in taking such films as had been shown, and also with his remark that the specification was a tool or implement, not a complete text book. If a street was to be lighted adequately it must be examined and its characteristics noted; and the specification must then be applied with common sense. The information called for in the specification could be of the utmost value to a competent engineer. Referring to the case of concrete roads mentioned by Mr. Harper, Mr. Smith explained that the figures in the paper were taken from work done by M. Cohu, who had not dealt with concrete surfaces, but in due course figures for concrete surfaces would be forthcoming. He felt that he was not competent to reply to Mr. Harper as to the responsibilities of the municipal engineer.

The suggestions of Mr. Damant with regard to the headings in Table 1, he agreed, were the more logical. Table 2 surely indicated quite clearly that the road surface was of considerable importance, and also that other backgrounds were of some significance. The control of reflections from houses was naturally very limited, but more could be done with fences and the like. As regards measuring illumination on a vertical test plate, he did not think he was breaking any confidence in saying that a committee of the B.S.I. had been considering various suggestions amongst which that particular point was included.

There were plenty of good installations with high candle-power components near the horizontal, but there were others which had not that characteristic. He himself agreed with Dr. English that high candle-power near the horizontal was not absolutely essential, and at times might lead to undesirable glare. There were other ways of securing good visibility, and more work on this point was needed. Dr. English had put his finger on the spot when he said, in effect, that special treatment was necessary for the different types of roads. For lighting long arterial roads—such as that mentioned as being near Berlin—there was more than one effective method available. In the case of roads winding in and out, then it was essential to study each on its merits.

Mr. Sandeman had seemed to imply that the drafting of a specification was an easy matter, but it was not. Whatever was done with a specification, something must be left to the judgment of the public lighting engineer. He did not think the idea of relying on standard sections of roads laid down at the National Physical Laboratory or elsewhere was feasible. At the same time, the B.S.I. welcomed useful suggestions and would consider them. Glare had also been mentioned by Mr. Sandeman, but its effect could not be defined as merely inversely proportional to the mounting height. He only wished it were!

Whilst agreeing with Mr. Wilson that lighting engineers are able to design good installations to their own satisfaction, it did not follow that the members of a council would consider these installations satisfactory. Their views might not be the same as those of the technicians, who should not assume too readily that they knew all about this subject. Many modern units which had a high component near the horizontal also gave a good general distribution. But the percentage of the flux allotted simply to creating the brightness of the road was often surprising. He welcomed Mr. Wilson's remarks with regard to photographic technique and looked forward to Mr. Hopkinson's paper on the subject.

An important point had been raised by Mr. Dow, when he referred to the possibility of an upper limit of brightness. In practice it was a rare occurrence for this degree of brightness to be obtained, but he *had* seen installations in which it might fairly be said that the upper limit had been reached. However, in most cases this was not a problem.

On the point mentioned by Mr. Burman, it was the fact that M. Cohu, in a paper in France, had suggested that the backs of motor cars should be painted black and white so as to make them more visible. It also seemed to be an excellent plan to have the mudguards of cycles painted white. The "sphere" method of testing, mentioned by Mr. Burman, had actually received some attention in another form. Consideration had been given to the possibility of measuring illumination with vertical tubes. If Mr. Burman went any further with his idea the committee would be glad to hear from him.

Undoubtedly, as Mr. Waldram had said, road brightness was important and desirable, but when it came to specifying it and making it the subject of a contract and obligation, then the difficulties began. It was not because those who were assisting to draft the specification thought brightness was of no importance that such a clause was absent from the specification, but because of the great difficulty of drafting such a clause in a form which could be conveniently applied and equitably used in practice.

ERRATA

Our attention has been drawn to an error in the account of the Proceedings of the Conference of the Association of Public Lighting Engineers which appeared in our last issue. We understand that Mr. A. S. Parsons, Borough Engineer and Surveyor of Reading, did not take part in the discussion of Mr. Allbright's paper, but that Mr. H. P. Pascal, Assistant Mains Engineer of the Reading Corporation Electricity Department, did so.

We have also to correct an obvious oversight in the account of the Tour of the Lights o' London, which appeared on page 339. The installation of Supervia Gas Lamps, which attracted so much attention, was, of course, that in Blackfriars-road, not in Grosvenor-road as suggested in the note.

The Importance of Kinematical Factors in Roadway Illumination

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(Delivered at the Twelfth Annual Meeting and Conference of the Association of Public Lighting Engineers, held in London during September 9th to 12th, 1935.)

Introduction.

The subject of roadway illumination is sufficiently large and complex to present scope for many types of investigation. Since roadways are illuminated solely because of the existence on the roadway of moving observers and the things they observe, it seems logical that some part of any general investigation should concern the kinematical aspects of roadway lighting, and the authors are engaged upon studies in which these aspects are kept prominently in mind. This paper consists of a preliminary account of some of this work, and as such can be subjected to comment and criticism and will, no doubt, be subject to modification. But road lighting is by its nature—and we may refer particularly to the difficulty of large scale experiment—a subject in which theory and laboratory experimentation must be continually checked by, and sometimes subordinated to, the practical experience of lighting engineers. We, therefore, appreciate very much this opportunity of discussing our lines of thought with this audience, whose practical experience of street-lighting problems is so extensive.

During recent years there has been a gratifying increase in interest in both the scientific and practical side of road lighting. A considerable amount of laboratory work is being done in many countries, and, in this country at least, extensive new installations are regularly completed. Our knowledge of illuminants now enables us to make economical lamps of the light outputs that experience has shown to be desirable, and knowledge of lantern design and reflector and refractor materials is increasing. Together with this occur great improvements by road engineers and an increasing flood of traffic on the roads they design. We feel, with these facts and others, that the stage is all set for a great extension of road lighting.

It is natural that there is a great desire by all concerned for some simple yardstick that will measure road lighting, so that this may be improved, and designed and installed to agreed specifications, which will give the maximum benefit to the user, coupled with the economy and reliability that is the responsibility of the installing authority.

Now there are many things that can be measured in connection with a road lighting installation, and that may, in some form or combination, serve as this yardstick. We list some of these below:—

Illuminant output,
Lantern distribution,
Lantern spacing,
Lantern height,
Road dimensions,
Average, or distribution of, luminous flux on roadway and backgrounds,
Average, or distribution of, road brightness, and so on.

It is not always realised that none of these, nor any combination of them, measure the goodness or the satisfactoriness of a road-lighting installation. That must always be a matter of judgment.

We wish to emphasise that roadway lighting is one of those subjects, and there are several, which require two distinct kinds of investigation, viz., the objective and the subjective. On the one hand, it is necessary to recognise fully the physical factors involved and to have a knowledge of the methods enabling these to be measured, and expressed in completely defined units applicable anywhere by any one. Then, on the other hand, it is necessary to know the recipe to which these various factors must be mixed to provide good lighting, and this is a matter of judgment, i.e., the treatment is subjective.

The two methods must run hand in hand. It is, for example, most necessary to be able to recognise the physical quantities involved and to be able to measure them, but the physical quantity itself is not road lighting. The work on road brightness by Millar[1] and others, and more recently that published by Waldram[2] and by Cohu,[3] may be mentioned to illustrate this point. The brightness of the road surface is a most important factor in roadway lighting, and the full recognition of this, and its measurement under various circumstances (together with a measurement of all background brightnesses) will undoubtedly lead to greater knowledge of road lighting. If, however, the degree of surface brightness is used as a figure of merit for the roadway lighting, as it may under some circumstances quite properly be used, this merely means that in the judgment of some one or some body, a given amount of brightness provides a certain effectiveness of lighting.

It is only comparatively recently that surface brightness and silhouette vision have been recognised generally as relevant factors. There may well be others, as yet unrecognised, present in varying degree, and which affect the quality of the roadway lighting. Until the existence of all factors is recognised there is the obvious danger of concentrating attention on the ones that are known, with the result that each factor in turn may suffer undue prominence by reason of novelty, instead of being smoothly incorporated in a satisfactory working theory.

Since even when all factors are recognised their degree of effectiveness will be a matter of judgment, we have been led to consider closely this question of subjective treatment, and the possibility of developing its pronouncements into some quantitative form.

These considerations have led us to believe that an examination and evaluation of road-lighting schemes by a subjective method should be profitable.

It is always possible to learn from others, and we have been impressed by the similarity between the

1 P. S. Millar. Transactions I.E.S. Vol. V., 1910.
2 J. M. Waldram, "Illuminating Engineer," pp. 305 and 309, 1934.
3 M. Cohu, Société Pour Le Perfectionnement de l' Éclairage, March, 1935.

general problems of road lighting and those of architectural acoustics and of noise measurement.[4] Prof. Sabine[5] has written a series of papers on the former, and we quote from his introduction to these.

"The problem of architectural acoustics required for its complete solution two lines of investigation, one to determine qualitatively the physical conditions on which loudness, reverberation resonance, and the allied phenomena depend; the other to determine the intensity which each of these should have; what conditions are best for the distinct audition of speech, and what effects are best for music in its various forms. One is a purely physical investigation, and its conclusions should be based and should be disputed only on scientific grounds; the other is a matter of judgment and taste, and its conclusions are weighty in proportion to the weight and unanimity of the authority in which they find their source. Sufficient progress has been made to justify the assertion that the physical side of the problem is solvable, and that it should be possible ultimately to calculate in advance of construction all the acoustical qualities of an auditorium.

"The second part of the problem now being started, the question as to what constitutes good and what constitutes poor acoustics, what effects are desirable in an auditorium designed for speaking, and even more especially in one designed for music, is not a question in physics."

Prof. Sabine goes on to explain how this is a matter of judgment and taste. His remarks are so much to the point that it has been interesting to rewrite some paragraphs, altering them by the substitution of phrases applicable to road lighting for those applicable to architectural acoustics, for which the words, of course, were originally written. With acknowledgment to Prof. Sabine, we give this rewrite below:—

"The problem of highway lighting requires for its complete solution two lines of investigation, one to determine quantitatively the physical conditions on which illumination, brightness, glare, and allied phenomena depend; the other to determine the intensities which each of these should have, what conditions are best for high-speed arterial traffic, and what effects are best for slower urban traffic in its various forms.

"One is a purely physical investigation, and its conclusions should be based, and should be disputed, only on scientific grounds. The other is a matter of the requirements of all classes of user, and its conclusions are weighty in proportion to the weight and unanimity of the authority in which they find their source. Sufficient progress has been made to justify the assertion that the physical side of the problem is solvable, and that it should be possible ultimately to calculate in advance of construction all the optical qualities of the field of view of a road user.

"The second part of the problem now being started, the question as to what constitutes good, and what constitutes poor lighting conditions, what effects are desirable in the lighting of a road designed for arterial traffic, and even more especially in one designed for urban conditions, is not a question of physics. It is a physiological and psychological problem, and therefore not one for which the authors are especially qualified, and would not be undertaken here were it not in the first place absolutely necessary in order to give effect to the rest of the work, and in the second place were it not the plan rather to gather and give expression to the judgment of many others acknowledged as qualified to speak, than to give expression to the taste and judgment of a few.

"It is thus the purpose to seek the judgment of road users in regard to lighting effects and if possible to present the results in a form available to lighting engineers. This will be slow and difficult work and it is not at all certain that it will be possible to arrive, even ultimately, at a finished product. It is worth undertaking, however, if the job as a whole is worth undertaking, for without it the physical side of the investigation will lose much of its practical value.

"Thus it is of little value to be able to calculate in advance of construction and express in numerical measure the brightness distribution over the entire field of view, unless one knows also in numerical measure the effect which is desired."

One of the authors has had experience of the application of the subjective method to the classification of sound reproducing theatres. Here a satisfactory authority for the goodness of the acoustics was box-office receipts. In spite of variations in the quality and subject matter of the films it was possible to classify auditoriums into good, bad, and indifferent by the criterion of weekly receipts and reports of service engineers. This classification, and an examination to determine the physical differences that existed between the best and worst halls, provided the starting point for an investigation which has resulted in the design of improved apparatus and a thorough knowledge of the acoustical properties of theatres.

Application of Subjective Method to Lighting Problems

It was the success of the subjective classification in the solution of the problems connected with theatre acoustics that lead the authors to attempt a similar classification into order of merit of existing lighted roads, but the difficulty of obtaining an unbiased concensus of opinion had to be faced. In the case of the theatres, the weekly comments of the service engineers and theatre manager on the general sound quality and the popularity of the hall gave a fairly reliable indication, but no such data exists for lighted roads.

Many schemes were suggested, such as asking parties of observers to fill in data sheets, to make visibility tests on the road, etc., but in the opinion of the authors these suggestions were all open to criticism as tending to bias the attention of the observers on one or more particular factors.

The suggestion finally adopted was to arrange for parties of observers to tour a number of lighted roads and to place these in order of merit, without any other restriction. The general instruction given to the observers was as follows:—

"With a view to determining to what extent modern road lighting is suited to individual observers, it is proposed to motor a number of observers to lighted roads of various types.

"Each group of lighted roads viewed will consist of approximately six separate sections. The observer is asked to note his impression of each section and, upon completion of the group to place the sections in order of merit on the test sheet provided. If an observer feels that two sections are of equal merit, this fact should be indicated. For the investigation to be of value, it is most important that genuine individual opinions are gathered, and observers are asked not to make audible comment upon test roads during the observations."

The parties consisted of any number of observers (preferably not less than ten) and included a majority of non-technical men without direct interest in, or preconceived ideas about street lighting. Some technical men were included in each party to obtain a comparison between technical and non-technical observers.

The observers are asked to complete the form shown on Specimen Sheet No. 1. The results are then collected and analysed as may be thought convenient and correct. The method of analysis we have

4 The Measurement of Noise with Special Reference to Engineering Noise Problems, B. G. Churcher, A. J. King, H. Davis.

5 Collected Papers on Acoustics, W. C. Sabine, pp. 69-70.

adopted is the simple one of enabling the order of merit to be assessed visually and the illustrations mentioned below are self-explanatory.

Results of Some Tests.

It will be noted that the simplicity of this method is extreme. A party of non-technical people are merely taken over roads and asked to note their impressions and to place the roads in certain groups in order of merit. In spite of the simplicity some very consistent results are obtained.

Results are given here on four tests which are respectively:—

H.P. mercury vapour electric discharge lighting, Midland group	7 observers
H.P. mercury vapour electric discharge lighting, London group	10 „
Tungsten filament lighting Leicester group No. 2	36 „
Tungsten filament lighting Leicester group No. 3	36 „

In every case the installations have used lamps and lanterns of various makes.

Fig. 1 shows the results of one of the earliest tests on arterial roads in the Midlands, lighted by 400-watt electric discharge lamps of various makes. These roads were fairly widely distributed, but, as can be seen, the observers had little difficulty in assessing the relative merit. Only seven observers were used, and this number is on the low side.

Fig. 2 shows a similar set of results by an entirely different group of ten observers on arterial roads in the London area. Again all installations were fitted with 400-watt electric discharge lamps of various makes. The first and second and last roads in order of merit were placed very consistently.

Figs. 3 and 4 show the results obtained on a test of tungsten filament lighting carried out by thirty-six observers in Leicester. After a number of results had been obtained elsewhere we had an opportunity of discussing the method with Mr. T. Wilkie, Public Lighting Engineer of Leicester, who kindly offered to obtain similar independent data for some of the roads of Leicester. We take this opportunity of thanking Mr. Wilkie and his staff for the data so obtained. It should be noted with regard to these results that the observers were divided into two groups, motorists who toured the roads in cars, and pedestrians who walked through the installations; the roads were carefully selected as being the best of their kind available, i.e., of a similar effectiveness, and, therefore, constituted a severe test of the method; various systems of lighting were included, such as side mounting, central suspension, low cut-off to minimise glare, and high cut-off. The road conditions varied throughout.

The results shown in Fig. 3 are very definite, and the first, second, and sixth positions are clearly indicated. The intermediate positions show somewhat more spread, but are still fairly clearly defined.

In Fig. 4 the results are not so definite. First and second roads in order of merit are shown up well.

Three points of interest are worth noting at this stage.

Referring to Figs. 3 and 4, observers, numbers 1 to 21, are motorists, and observers 22 to 36 are pedestrians, for the purpose of, and during, the test.* There is consistent agreement between motorists and pedestrians throughout the tests—if anything the pedestrians show a rather closer agreement between themselves than the motorists. It must not be inferred from this result that there will always be the same agreement between the motorist and the pedestrian, but there is no doubt about the result in this instance.

It was thought there might be considerable difference between the opinion of technical men and the laymen, but the results of all tests indicate that this is not the case. Of the thirty-six observers in the Leicester tests, numbers 4, 7, 12 and 21 are skilled observers directly interested in road lighting. The closeness of their classification to the average is remarkable, the same results being shown in other tests.

The third point of interest arises from a study of the results of observers who show the greatest deviation from the average, e.g., numbers 3, 5, 17, 18 and 19 on (Fig. 3) who had adjudged what is generally agreed to be the worst installation as the best. On all other roads these observers are fairly close to the average. Similarly, Nos. 10 and 20 show disagreement in test 6 (Fig. 4), but are fairly close on all other tests. This result emphasises the need for a large party of observers, and may account for the disagreement sometimes found when two or three persons express an opinion on a single installation.

Value of Subjective Method of Assessment.

The method outlined above enables in a simple manner the effectiveness of groups of road lighting schemes to be compared. The method has essentially a kinematical basis and takes into consideration *all factors* influencing effectiveness under actual working conditions. For instance, if arterial roads are under consideration, the observers will tour the roads at the speeds, and under the conditions for which the roads were designed, and for urban roads the observers will be divided into pedestrian and slow-speed traffic. We feel that this method, with some refinement, and with careful consideration given to the characteristics to be included in any one group, is capable of giving results of value. Certainly the consistency obtained on the results so far taken indicate that we have a method giving a basis for further investigation.

Investigations Based Upon the Subjective Method of Assessment.

The first step in the investigation which follows the assessment is the collection of all possible data concerning the road surface and its environments, the installation layout, and lantern characteristics, etc., i.e., the measurement of all physical factors that can be measured, and the provision for those that cannot be measured by full descriptions and remarks.

This information is tabulated, together with the "order of merit," and studied with a view to determining what factors and conditions are concurrent with effectiveness. If any factor to which it is possible to assign a magnitude were found to give a definite relationship when plotted against "order of merit," then, undoubtedly, for the type of installation concerned that factor would be a criterion of effectiveness.

Furthermore, the absence of any factor showing such relationship with effectiveness is a sure indication either that all the factors influencing effectiveness have not been recognised, or that some factor is wrongly or insufficiently represented.

Representation of Factors Influencing Effectiveness.

Tabulated data for three of the groups mentioned above, arranged in order of merit, are shown in Figs. 5, 6, and 7. It is seen that one of the factors included is "Lantern Characteristics." The light distributing characteristics of the lantern determine not only the brightness distribution obtainable with various types

* It was subsequently ascertained from Mr. Wilkie that the pedestrians were, in fact, non-motorists, i.e., they neither owned nor drove motor vehicles.

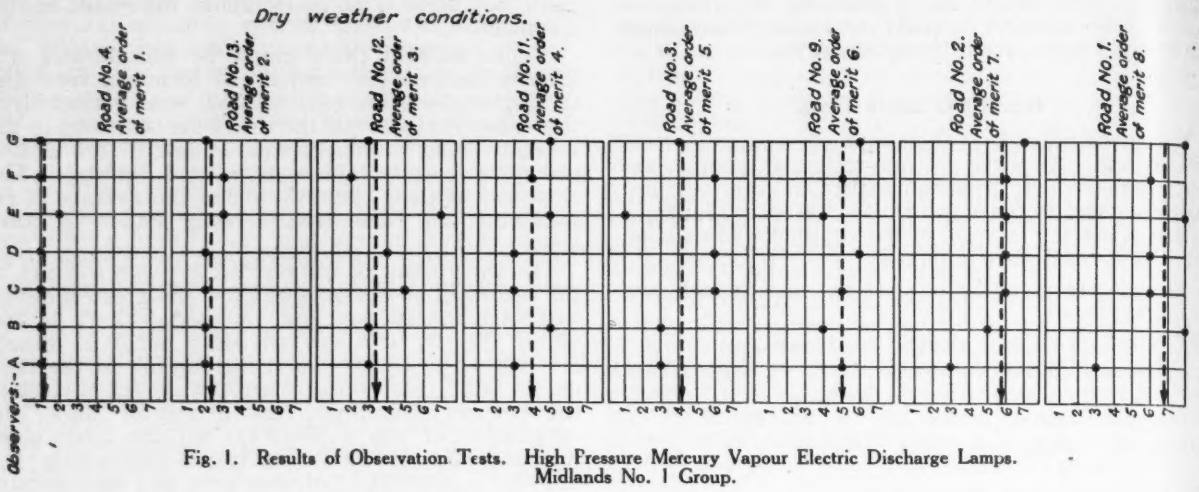
Dry weather conditions.
Road No.4. Average order of merit 1.
Road No.13. Average order of merit 2.
Road No.12. Average order of merit 3.
Road No.11. Average order of merit 4.
Road No.3. Average order of merit 5.
Road No.9. Average order of merit 6.
Road No.2. Average order of merit 7.
Road No.1. Average order of merit 8.
Observers:- A B C D E F G

Fig. 1. Results of Observation Tests. High Pressure Mercury Vapour Electric Discharge Lamps. Midlands No. 1 Group.

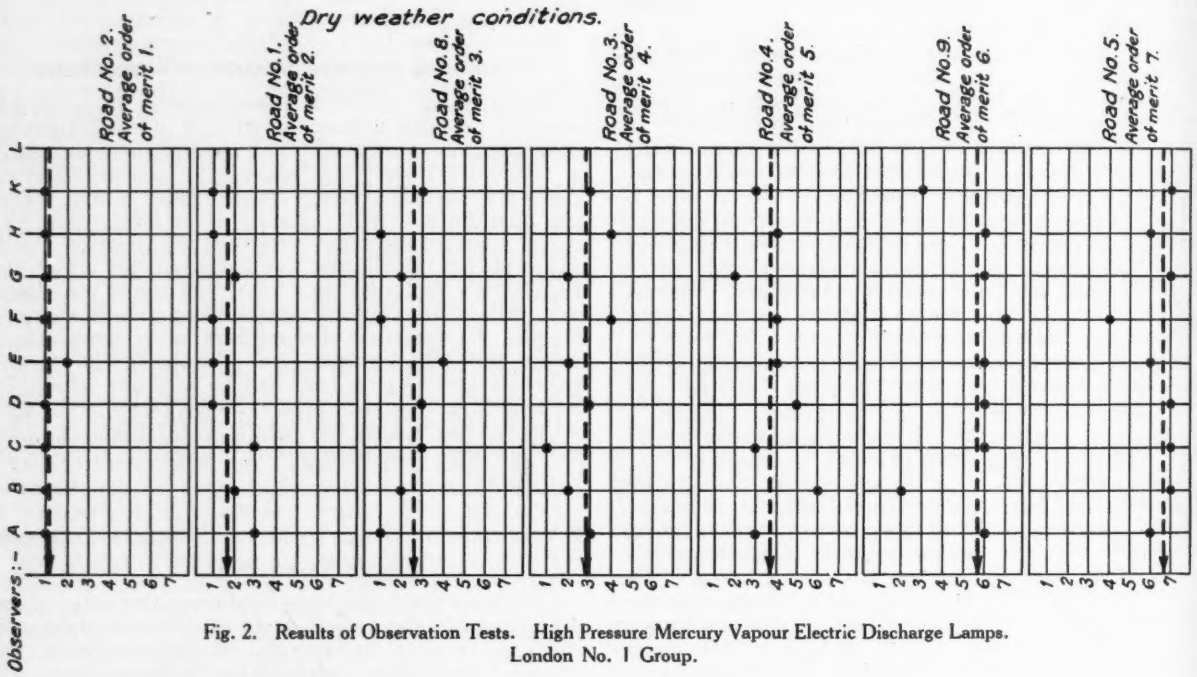
Dry weather conditions.
Road No. 2. Average order of merit 1.
Road No.1. Average order of merit 2.
Road No.8. Average order of merit 3.
Road No.3. Average order of merit 4.
Road No.4. Average order of merit 5.
Road No.9. Average order of merit 6.
Road No.5. Average order of merit 7.
Observers:- A B C D E F G H K L

Fig. 2. Results of Observation Tests. High Pressure Mercury Vapour Electric Discharge Lamps. London No. 1 Group.

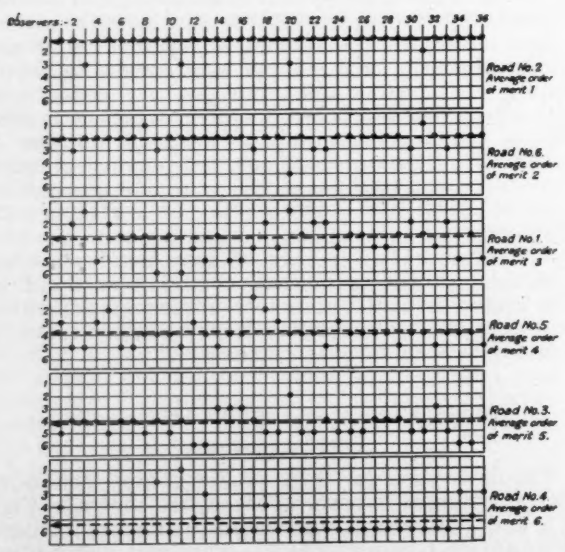
Road No.2 Average order of merit 1
Road No.6. Average order of merit 2
Road No.1. Average order of merit 3
Road No.5 Average order of merit 4
Road No.3. Average order of merit 5.
Road No.4. Average order of merit 6.

Fig 3. Results of Observation Tests. Tungsten Filament Lamps. Dry Weather Conditions. Leicester No. 2 Group.

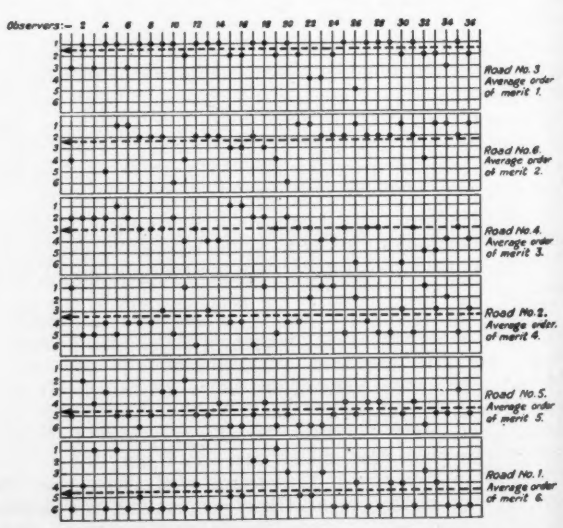
Road No. 3 Average order of merit 1.
Road No.6. Average order of merit 2.
Road No.4. Average order of merit 3.
Road No.2. Average order of merit 4.
Road No.5. Average order of merit 5.
Road No.1. Average order of merit 6.

Fig 4. Results of Observation Tests. Tungsten Filament Lamps Dry Weather Conditions. Leicester No. 3 Group

of road, pavement, and other background surfaces, but also, from a glare standpoint, the effectiveness of any level of background brightness.

Thus the method of representing lantern data should at least place on record all the information required for the determination of all background brightnesses, and any glare effects which it may be possible to analyse and express as a separate factor. However, with reference to Figs. 5, 6, and 7, we have simplified for various reasons by representing lanterns by a signifying letter.

Fig. 5 embraces seven different roads fitted with five different types of lanterns. In each case the illuminant was a 400-watt mercury vapour electric discharge lamp. Road widths varied from 30 to 42 feet and lantern spacing from 120 to 180 feet.

The first four roads in order of merit have the same average brightness approximately, but there are marked differences in maximum brightness between roads 1 and 2 and roads 3 and 4, *the latter pair* having over twice the maximum brightness of the first pair.

The road adjudged first has the third highest test point figure, while the road having the highest test point is placed fourth.

Fig. 6 concerns a group of six roads all fitted with tungsten filament lamps and with road widths varying from 32 feet to 40 feet. Here the road adjudged

		INSTALLATION CHARACTERISTICS.								LIGHT DISTRIBUTION DATA.			STREET CHARACTERISTICS.					BRIGHTNESS (E.F.C.)		
Installation No.	Order of Merit.	Total lumens per ft. run.	Watts per ft. run.	Formation.	Spacing.	Mounting Height.	Overhang.	Road Width.	Pavement Width.	Size of Lamp.	Lantern Characteristics.	Mean Test Point. Illumination (F.C.)	Carriageway Surface.	Pavement Surface.	Other Backgrounds.	Kerbs.	Other Details.	Carriageway.	Pavement.	Other Backgrounds.
							ft. in.													
2		66.6	2.22	S	180	27	0	30	8	400	A	.194	Light coloured chips tar sealed. General colour grey, Rough surface, slightly polished.	Concrete Slabs.	Brick fences and hedges. Houses set back 15 ft. Generally of low reflectivity	Granite.	Trees cause some obstruction.	Max. .95 Min. .15 Av. .23	Av. .13	—
1	2	100	3.33	S	120	25	3 6	42	10	400	B	.255	12ft. outers tight oblique setts, very slightly polished. 18ft. centre dark square setts tar-sealed. Medium polished.	Concrete Slabs.	Dark buildings and small shops.	Granite.	2 sets tram lines.	Max. .85 Min. .11 Av. .20	Av. .20	—
8	3	89	2.96	S	135	25	8	36	12	400	C	.124	*Outers.* Wood blocks tar sealed. Well-laid and highly polished. *Centre* ditto, but rougher and less polished.	Concrete Slabs.	Very dark, high brick walls. Line of white stone 4 ft. above ground. Generally poor.	Granite.	2 sets of 3 tram lines.	Max. 2.5 Min. .03 Av. .23	Av. .12	—
3	4	100	3.33	S	120	25	0	39	10	400	D	.32	*Outers.* Highly polished dark tarmac. *Centre.* Tarmac and setts slightly polished.	Concrete Slabs.	Small shop. and buildings. Generally dull.	Granite.	2 sets tram lines.	Max. 2.4 Min. .047 Av. .23	Av. .23	—
4	5	80	2.67	S	150	25	4	35	—	400	B	.157	*Outers.* Highly polished stone setts. Dark Grey. Some tarred. *Centre.* Smaller stone setts, tar sealed and fair polish.	Concrete Slabs.	Brick and Iron railing fences. Generally poor.	Granite.	2 sets of 3 tram lines.	Max. 1.4 Min. .036 Av. .20	Av. .12	—
9	6	75	2.5	S	160	25	3	35	10	400	C	.081	Wood blocks, tar sealed. Highly polished.	Concrete Slabs.	Dark iron fences and brickwork. One side partly in shadow from trees.	Granite.	—	Max. 1.2 Min. .03 Av. .125	Av. .064	—
5	7	100	3.33	S	120	25	4	30	10	400	E	.080	Tar-sealed wood blocks. Slightly polished.	Concrete Slabs.	Stone walls and buildings of low reflectivity.	Granite.	—	Max. .58 Min. .07 Av. .056	Av. .066	—

Fig. 5. Tabulated data on Installations equipped with 400 watt High Pressure Mercury Vapour Electric Discharge Lamps (London Group No. 1) Dry Weather Conditions.

first has both the highest test point illumination and highest maximum road brightness, with a diversity of the latter of approximately 30 to 1.

In general, the order of merit follows the same order as that of maximum road brightness. This is a different finding from that observed on the first group.

Fig. 7 contains data for six roads varying in width from 44 to 60 feet and illuminated by tungsten filament lamps. Here the road adjudged first has the highest figure for maximum road brightness, but a second road having the same figure for maximum road brightness is placed last but one. The diversity factors are respectively 33 to 1 and 150 to 1.

The road placed last should, on road brightness figures, be placed superior to the road placed third. In this case the magnitude of mean test point illumination definitely places the two installations high and low in the list.

We would emphasise that no general conclusions as regards importance of various factors should be drawn from the results given in this paper. Before such conclusions can be drawn it is necessary to have data from a considerable number of test sections.

The above examples illustrate the general course of this branch of the work that is being undertaken. One value that it has had has been to emphasise the necessity for collecting the completest data on the road and for very extensive measurement of such things as background brightnesses. This part of the work takes considerable time. The actual task of observing a group of roads and ascertaining their order of merit can be completed in a comparatively short space of time, but a very large number of groups should be surveyed. We think it would be of value if more of this could be done, and we have included in our paper complete directions should any of you desire to follow up this line of investigation, and to make for your own areas a subjective examination and classification of the main lighting installations.

Owing to the numerous factors involved over which the lantern designer, and even the lighting engineer, has no control, the method cannot directly be employed for comparing lantern characteristics, or any one feature of installation designs, unless all other conditions are known to be absolutely identical.

The method is, however, directly applicable to practical problems in the following manner. After placing, say, six installations in order of merit, an

			INSTALLATION CHARACTERISTICS.							LIGHT DISTRIBUTION DATA.			STREET CHARACTERISTICS.					BRIGHTNESSES (E.F.C.)		
Installation No.	Order of Merit.	Total Lumens per ft. run.	Watts per ft. run.	Formation.	Spacing.	Mounting Height.	Overhang.	Road Width.	Pavement Width.	Size of Lamp.	Lantern Characteristics.	Mean Test Point Illumin't'n(F.C.)	Carriageway Surface.	Pavement Surface.	Other Backgrounds.	Kerbs.	Other Details.	Carriageway.	Pavement.	Other Backgrounds
						ft. in.	ft. in.	ft. in.	ft. in.											
2	1	44.4	3.33	P	120	21 9	10 4	40 0	10 0	2x 200	1	.18	Wide centre secn. of stone setts. Outers of smooth dark tar slightly polished. Well laid.	White concrete slabs.	Park houses set back 30ft., 50ft. Trees, some light coloured verticals. Poor.	Granite.	Tram lines.	Max. .6 Min. .022	Max. .06 Min. .033	—
6	2	64.1	4.16	S	120	17 9	2 6	32 6	9 6	500	10	.15	Smooth tarmac, fairly polished.	Concrete slabs.	Large shops, some light coloured. Good.	Granite.	Tram lines.	Max. .46 Min. .1 Av. .15	Av. .1	—
1	3	22.2	1.66	S	120	20 0	2 6	32 0	9 3	200	7	.05	Dark tarmac. Smooth. Slightly polished. Streaking just visible.	White concrete slabs.	Houses and small shops. Fair.	Granite.	Unit on wrong side at bend.	Max. .31 Min. .01	Max. .013 Min. .002	—
5	4	22.2	1.66	S	120	18 4	2 4	33 9	9 0	200	9	.085	Wide centre secn. of stone setts. Tar outers fairly polished.	Concrete slabs.	Palisade houses. Part fields. Trees. Poor.	Granite.	Tram lines.	Max. .18 Min. .003 Av. .013	Max. .013 Min. .002	—
3	5	35.5	2.5		120	18 6	2 0	38 0	11 0	300	3	.12	Very wide centre secn. of stone setts. Narrow tarmac outers slightly polished.	Part concrete slabs, part tarmac	One side houses & shops, other side c'crete hall and hoardings. Trees & dark houses. Bad.	Granite.	Tram lines 2 sets.	Max. .15 Min. .003 Av. .011	Av. .01	—
4	6	35.5	2.5	S	120	18 6	2 0	38 0	11 0	300	8	.05	Very wide centre secn. of stone setts. Narrow tarmac outers slightly polished.	Concrete slabs and tarmac in shad. of trees.	None visible due to trees. Very bad.	Granite.	Tram lines.	Max. .05 Min. .0028 Av. .0078	—	—

Fig. 6.—Tabulated data on Installations equipped with Tungsten Filament Lamps. (Leicester No. 2.) Dry Weather Conditions.

Installation No.	Order of Merit.	INSTALLATION CHARACTERISTICS. Total lumens per ft. run.	Watts per ft. run.	Formation.	Spacing.	Mounting Height.	Overhang.	Road Width.	Pavement Width.	LIGHT DISTRIBUTION DATA. Size of Lamp.	Lantern Characteristics.	Mean Test Point Illumin't'n(F.C.)	STREET CHARACTERISTICS. Carriageway Surface.	Pavement Surface.	Other Backgrounds.	Kerbs.	Other Details.	BRIGHTNESS (E.F.C.) Carriageway.	Pavement.	Other Backgrounds.
						ft. in.	ft. in.	ft. in.	ft. in.											
3	1	64.1	4.16	C	120	20 8	—	60 6	13 6	500	4	.12	Polished tarmac, lightish colour.	Concrete Slabs.	Large shops, forming useful backgrounds.	Granite	Tram rails	Max. 3.0 Min. .09	Av. .067	—
6	2	44.4	3.33	P	120	22 0	10 7	54 6	12 9	2 x 200	1	.19	*Outers.* Tarmac, medium polish. *Centre.* Stone setts, slight polish	Tarmac	Stone wall one side. Other side fields. Poor.	Granite	Tram rails	Max. 0.6 Min. .036	Av. .067	—
4	3	64.1	4.16	S	120	23 9	1 6	57 0	14 0	500	10	.135	Polished tarmac, lightish colour. Well-laid surface.	Part concrete and part tarmac.	Mostly undeveloped. Black ashes. Bad.	Granite	—	Max. .36 Min. .012	Av. .03	—
2	4	64.1	4.16	S	120	19 1	2 6	44 0	13 0	500	11	.16	*Outers.* Tarmac, fairly polished. *Centre.* Stone setts, slight polish	Concrete Slabs.	Large palisaded houses. Good.	Granite	Tram rails	Max. .36 Min. .016	Av. .054	—
5	5	64.1	4.16	S	120	20 2	2 8	57 0	14 6	500	10	.11	Tarmac, slightly polished. Well-laid surface.	Concrete Slabs.	One side shops other undeveloped. Bad.	Granite	Tram rails	Max. 3.0 Min. .022	Max. .17 Min. .09	—
1	6	35.5	2.5	S	120	19 10	2 7	48 6	10 0	300	6	.07	*Centre.* Stone setts. *Outers.* Slightly polished tarmac.	Concrete Slabs.	Small shops & factories. Few trees. Good.	Granite	Tram rails	Max. .40 Min. .013	Max. .044 Min. .01	—

Fig. 7. Tabulated Data on Installations equipped with Tungsten Filament Lamps (Leicester No. 3), Dry Weather Conditions.

installation showing a relatively low effectiveness might be improved by a change of lantern, or of installation layout, or by treatment of the background surfaces.

Any improvement effected would then be shown in the order of merit obtained by a repeat test of the same group of installations, and preferably with a fresh group of observers.

Repetition Effects.

It is to be expected that the complete application of the subjective method, as outlined briefly above, may bring to light factors contributing to the effectiveness of road lighting whose importance has hitherto been little suspected. For example, as lighting schemes are extended, and it is to be hoped that in the future, arterial traffic routes between important cities will be artificially lighted, the order of merit given by a subjective examination may be influenced by repetition effects.

These can be present, due to the fact that road lighting is only possible by discontinuous units. In traversing these a pattern is repeated at a frequency that depends upon the spacing of the units and the speed of traverse. The elements of the pattern are variations of lantern brightness and angle of view, and variations of surface brightness. Now any such repetition effects are probably negligible in their effect on visibility on stretches of roadway which can be traversed in a comparative short space of time, but may become of importance if an observer is subjected to them for an hour or more.

As the angle of maximum cut-off and the distribution at other angles of a lantern is varied an observer driving at a steady speed will be exposed to corresponding varying conditions. The cyclic variation of light entering the observers eye will be different according to the design of the lantern. It is possible with some assumptions, to calculate this cyclic variation, and we are indebted to Mr. C. E. Fenwick of this laboratory for calculations which we are using. One representation of the cyclic variations possible is given in Fig. 8. Such curves, or some development

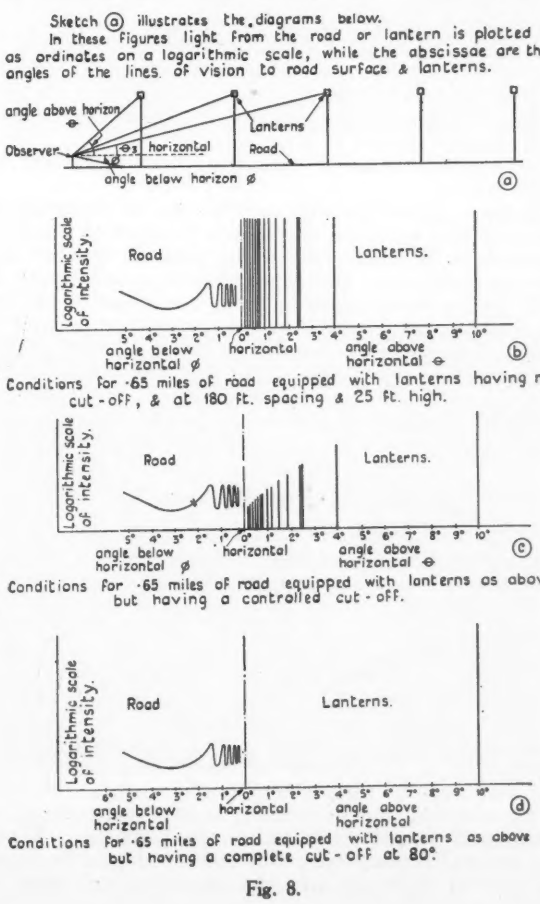
Sketch (a) illustrates the diagrams below.
In these figures light from the road or lantern is plotted as ordinates on a logarithmic scale, while the abscissae are the angles of the lines of vision to road surface & lanterns.
angle above horizon
Observer
horizontal
Lanterns
Road
angle below horizon ø
(a)
Logarithmic scale of intensity.
Road
Lanterns.
angle below horizontal ø
horizontal
angle above horizontal ⊖
(b)
Conditions for ·65 miles of road equipped with lanterns having no cut-off, & at 180 ft. spacing & 25 ft. high.
(c)
Conditions for ·65 miles of road equipped with lanterns as above but having a controlled cut-off.
(d)
Conditions for ·65 miles of road equipped with lanterns as above but having a complete cut-off at 80°

Fig. 8.

of them, form an additional way of representing lantern characteristics and the characteristics of installations, and it is of interest, by using them as described below, to examine the kinematical aspects of any change of lantern design in addition to the more usual study by way of polar diagrams, isofootcandle curves, etc.

It is not possible at present to find a number of long stretches of road, each fitted with a different modification of lantern design, and, therefore, recourse is being had to a model to enable the effects to be examined. Model roads have been in existence for some long time, and some are most elaborate, but owing to various reasons, one of which is the difficulty of accurate small scale reproduction of reflectors and refractors, they are seldom useful for any but elementary observations. Exception should be made here to the model road, some 250 feet in length, at Nela Park, Cleveland, on which some careful scientific experiments are being carried out.

The method we are adopting uses an apparatus consisting of a vertical screen, which can be illuminated to have a given degree of brightness by means of a light source of any desired radiation characteristics. This screen represents the background against which an object can be seen. The screen can be illuminated by the projection on to it of a photograph of a road, and further realism can be obtained by the projection of a moving picture of a road. By suitable arrangements a cyclic variation of background brightness can be produced if necessary.

Above the screen is placed one or more light sources representing the lanterns. In a simplified form this is a single light source, the brightness or area of which can be varied and which is directed towards the observer. The variation of brightness or area is calculated to correspond to that which would be produced by a given lantern, and is obtained by suitably shaping a cam or sector. The brightness of the vertical screen is adjusted to that given on the road by the lantern.

An observer is seated in front of the screen, and variation of lantern spacing and speed of travel is varied by varying the rate of rotation of the cam or sector, while variation of lantern design is obtained by varying the shape of the cam or sector. Under various conditions the time taken to recognise certain test objects placed in front of the vertical screen, after various times of exposure, tests the effect on visibility.

Before any conclusive results can be obtained in work of this nature a very large number of observations must be taken, and at the present time we can say no more than that the method seems likely to give useful results, and to form a method of obtaining further information on that important feature of lantern design, the distribution of light at angles near to the horizontal, and on the effects of a complete cut-off at a given angle, which is sometimes advocated, and of a graduated cut-off, which is probably preferable.

Study of Backgrounds.

An important kinematical aspect of roadway lighting concerns the behaviour and visibility of the components of the traffic stream at what may be called "danger points." By this term is meant any area in a road system in which there is a marked change of direction of travel of traffic, or the crossing of two or more traffic lanes. Such points need a more extensive consideration from that required by straight uninterrupted stretches of road. This consideration can be given by a careful study of the movement of traffic and of the backgrounds that are available to render that traffic visible. We are of the opinion that such study is best commenced by prolonged visual examination in daytime. There are several reasons why this survey should be made in natural lighting, and the strongest of these is that we require to simulate in artificial lighting the visibility and freedom from strain associated with daylight. If, therefore, a study is made of the movement of traffic, and of the backgrounds against which this movement is seen in daylight, we are in a position to attempt to establish an economical artificial lighting system—not, of course, of the same intensity, but approaching the same effectiveness. We succeed in this attempt if we can make the backgrounds sufficiently bright *for the same traffic movements to be seen against the same backgrounds as in daylight.*

We have used the word "prolonged" in connection with this study. That it is perforce lengthy can be seen by considering what is meant here by "movement of traffic." By traffic is meant all that is on the road, vehicles, cyclists, pedestrians, etc. While, on the average, the flow of this at junctions and bends will follow certain well-defined routes, any individual unit traversing an area follows an individual course, which, for various reasons, may depart from the average. For each position that a unit may occupy, the backgrounds, against which an observer in that unit is observing the positions of the other units, with which he has to avoid collision, are to some extent different. There are thus an infinite number of backgrounds against which an object may have to be silhouetted. The prolonged study is necessary to ensure that in the *unusual* positions that an observer and observed object may occupy, as well as the usual ones, the backgrounds are noted, so that the necessary brightness can be given to them.

It is the unusual positions that may be the cause of some inexplicable or narrowly averted collisions. As a whole, and for traffic following its normal course, an area on a road system may appear adequately lighted. There may exist, however, a course that some traffic unit can follow, such that an object occupying another given position is, because of some background condition, virtually invisible. Under such conditions, the possibility of a collision is great.

Moving observers approaching road junctions and bends should be given the opportunity of noting each other's positions, either by silhouette lighting, or, if necessary, by a combination of silhouette and direct-vision lighting, at the soonest possible opportunity, so that each may modify their courses to avoid collision. In these days of speed it is, we think, of greater importance to give vision in the *approaches* to a possible colliding spot than at the spot itself. Accidents are avoided by the continual alterations in speed and modifications of course that are possible when extended adequate vision is available. Poor conditions of lighting at the approaches to a corner or junction are worse than obviously blind regions.

In considering the equipping of a road with a new lighting installation one commences with a road plan, and usually economical considerations which allow a certain number of units of a given light output. It is generally desirable to space the units as uniformly as possible in order to serve the system as a whole to the best advantage. If, however, a preliminary survey, or existing knowledge of the site, indicate the existence of road junctions, severe bends, or other danger points, the decision as to spacing of units and to some extent lantern characteristics should depend upon the careful daylight study suggested. It may be advisable to take a number of photographs, or even short lengths of cinematograph film, from a number of positions so that close study can be made at leisure. Before fixing the positions of lighting units the individual responsible should have a complete mental picture of the road and other backgrounds, and the characteristics of the flow of traffic at any given point.

We have prepared a short moving film, which, with your permission, we will now show, and which illustrates some of the points that can be observed, directly during a study of backgrounds. Some pairs of photo-

Fig. 9.

Fig. 10.

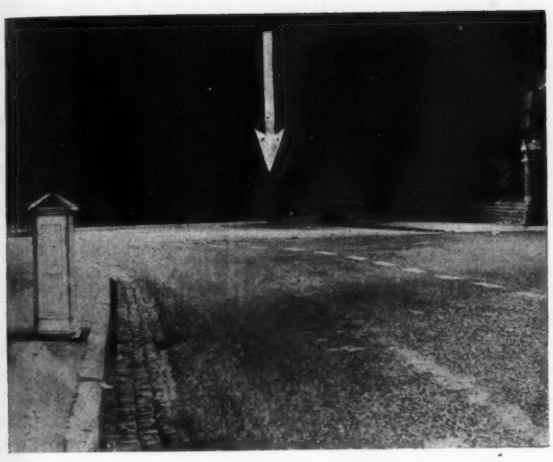

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

graphs are also reproduced here. In some parts of the film we have followed a cyclist, and in order that his position may be emphasised, he is dressed in white. In the photographs, and in other parts of the film. an increase of background brightness is produced, for the purposes of illustration, by the use of a white screen draped on the background. These white screens serve, of course, to render useful, light that is already provided, or can be provided by the lantern. In certain cases, an increase of the reflectivity of a background provides a most economicai way in which the necessary brightness can be provided. We venture to suggest that the possibility of doing this to certain backgrounds should be further considered. It is quite certain that on some arterial roads, fences and kerbs exist at bends that could be painted at the same time as are the "white lines," and that this would contribute just as much as do the latter to the safety of travel, provided such provision is accompanied by an adequate lighting scheme.

The photographs (taken under wet road conditions) in Figs. 9 and 10 illustrate an example of a side road joining up with a main road. This particular side road carries a good deal of cyclist traffic, turning both right and left into the main road, which carries mainly motor vehicle traffic. Visibility on the main road is excellent, but it is important that a motorist on the main road should be able to see the approach of the cyclist as soon as possible and before the latter enters the main road. The importance of the brightness of the vertical background in this connection can be seen by comparing the two figures.

Figs. 11 and 12 illustrate one part of a road junction at which five roads meet. At certain hours, one road discharging on to the junction carries an exceptionally large burden of traffic of all sorts. It will be noted from Fig. 11 that the important background for the pedestrian has but little brightness compared with the road. If the brightness of this background is increased visibility is much enhanced, and good opportunity is offered for the observation of the chance of collision before the colliding spot is reached.

Figs. 13 and 14 illustrate another lighting and traffic problem, viz., a change of gradient. In this case the danger is increased by a sharp turn to the right. In the case of an object on one part of the road, such as the pedestrian commencing to cross it, the road brightness plays but little part and brightness of the vertical background is essential. Fig. 14 shows the improved visibility obtained when this is provided, also the opportunity to ascertain as early as possible the existence of the bend. In the foreground brightness of the road is essential owing to the upward gradient of the road.

The above photographs are illustrative of certain features only. It is well appreciated that for road lighting to have the characteristic of high visibility an adequate degree of road brightness is necessary. In some situations the brightness of the vertical and other backgrounds bordering the road is of equal importance, and attention to lantern spacing and light control to secure this feature considerably enhances the effectiveness of the lighting.

We wish to acknowledge with grateful thanks the help of our colleagues in the preparation of this paper and in particular Mr. D. S. Morphey, Mr. J. Kemp, and Mr. W. H. Dawson.

We are indebted to Mr. H. Warren, Chief of the Research Laboratory, and to the Directors of the British Thomson-Houston Co. for permission to publish this paper.

DISCUSSION

Mr. H. Warren (Chief of the B.T.-H. Research Laboratory, Rugby) congratulated the authors on their enterprise in adopting the subjective method of investigation. The data assembled needed careful study, and the results to be interpreted with discretion; but they furnished an additional method which could be used with advantage when others had been applied and perhaps exhausted. He recalled two instances of subjective attack which had yielded good results. A marked difference of opinion between cinema authorities and acoustic engineers had been settled by taking votes on selected characteristics from several large bodies of heterogeneous listeners to the same collection of varied sounds. The second example was in connection with road lighting. Although his laboratory had been actively engaged upon sodium lighting for a long time he personally had felt little enthusiasm for this system because he failed to appreciate its psychological and physiological effects. But when he had visited what he thought was the finest sodium-lighted road in the world, with parties of ordinary road users, he appreciated fully the merits of this type of lamp.

Mr. T. Wilkie (Leicester) expressed his appreciation of the work described in the paper. In Leicester, too, they had been trying to get something which would explain visibility. He recalled a series of photographs taken with a camera the speed and aperture of which were subject to adjustment. One test was to determine how quickly an observer could see what was written on a background some distance away. The experiments seemed to show definitely that the new system of lighting improved seeing power. Unfortunately, however, the observer, standing beside the camera, was almost run down on three occasions by motorists, who evidently could not see him! In view of that experience he welcomed the paper as a serious effort to define the factors leading to good visibility Very often it was the man in the street who did not know anything about brightness, onion diagrams, etc., who was the final judge. In Leicester it had been found that this sort of opinion was worth having. In many cases one had no option but to ignore so-called principles of good lighting, simply because there were so many things over which the lighting engineer had no control. Street intersections must be well lighted because one could not ask property owners to have their fences painted white. Therefore, methods of general application and acceptable to users of the roads as a whole had to be devised.

Mr. F. C. Smith (Gas Light and Coke Co.) congratulated the authors on their pioneering work. He agreed with Mr. Wilkie that the reaction of the road user was a most important thing to ascertain. His company had tried to elicit this view with the aid of the fleet of vehicles which they owned—perhaps the largest privately owned in London. A meeting between drivers and technical men was arranged, and the former were encouraged to give their experiences of driving in London. It appeared that there were several parts of London well known to these men which they considered dangerous zones. Ultimately a charabanc drive through these areas was arranged and drivers were asked to record on sheets their answers to a series of questions. Many forms of lighting were included on the round. On the whole no very definite opinions emerged from this enquiry, but it was found that in a number of places where proper attention was given to back-

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ground the conditions were improved. It was very necessary to try to correlate the reactions of road users with technical aspects. In this way the explanation of many things at present obscure might be made clear; but he felt sure that the authors would agree that it was useless merely to collect opinions without studying their relation to technical data.

Councillor J. BYASS (Bridlington), as a delegate, expressed his appreciation at the manner in which the intricate problems of street lighting had been made clear in the papers read at the Conference. Although much of this work fell within the domain of the specialist, there was much of value to the layman, which they could apply in bringing about better street lighting in their various districts.

Mr. J. M. WALDRAM (G.E.C. Research Laboratories), in congratulating the authors, remarked that he himself has perhaps been particularly active in troubling the Association with intricate diagrams! It was a relief to turn to a real practical aspect. Much might be learned merely by going about with one's eyes open as the authors had done. Observations of maximum and minimum brightness might be supplemented by examination of the places where they occurred. A limit should be put to the positions in which these measurements were made. There was something to be said for confining them to really important regions of the road. He recalled three maxims for boy scouts which had a bearing on visibility. Firstly, that things were most easily visible when seen against the white sky or a uniform light background (the white screens used on cricket grounds and the white screens put behind railway signals when the natural background was dark were instances); secondly, in order to be really invisible one should get against a patchy background, which recalled the principles of camouflage; thirdly, it was great aid to invisibility if one kept still. To those afraid of the complexity of kinematical aspects, it might be pointed out that it was almost always easier to see something in motion than something stationary.

Councillor S. F. LANGRIDGE (Poole) also expressed his appreciation of the value of these conferences to councillors, who were thus led to understand something of the problems with which their officials had to deal. His experience as an official of the Sudan Government for twenty-four years had impressed upon him the need for good illumination on the road. It had been his privilege to put the first motor transport from the top of the White Nile to the Belgian Congo and he had then formed the conviction that it was better to have no lights at all than to have a roadway badly lighted.

Mr. FENWICK (New Zealand) drew attention to the continual increase in traffic on English roads. To widen these roads to take the additional traffic would involve vast expenditure, whereas, if they were properly lighted, the same traffic could be accommodated with a smaller width of road and at less cost. If arterial roads were to be really well lighted some form of central control seemed essential.

Alderman A. HILL (Leicester), after referring to the value of such conferences, remarked on the importance of the financial aspect. Since he had been attending these conferences, however, there had been a great improvement in the outlook of Town Councils towards expenditure on lighting. He welcomed the efforts of the Association in trying to make the streets as safe by night as by day.

Councillor P. C. VESEY (Chairman, Highways Committee, Barking) likewise expressed his interest in the Conference and commented especially on the international aspect of its work and the opportunity it afforded of hearing from representatives abroad. In regard to expenditure on street lighting, he remarked that local authorities must have assurance that lighting engineers could deliver the goods!

Mr. WADSWORTH (B.T.-H.) remarked that this paper, like that by Mr. Smith and Mr. Sawyer, had rather emphasised the large number of factors which affected visibility. He would like to know whether the illumination in foot-candles on the road and the brightness of the road were not the fundamental things to be determined; other matters could be decided after these two primary factors had been agreed.

Councillor W. COOPER (Wandsworth) congratulated the research laboratories of both the gas and electrical industries on the research work being carried out in connection with street lighting. As a representative of one of the London boroughs, he had had the privilege of seeing a considerable amount of experimental work with both forms of lighting. One important point was the lighting of certain minor streets, which were being constantly used by drivers round London in order to avoid the busier thoroughfares. Such streets now needed to be better lighted than in the past.

Mr. EDE (B. T.-H.), referring to the analogy between hearing and seeing that had been drawn in the paper, pointed out that reproduction of sound could not at the present time be undertaken exactly because of the bi-aural effect of the two ears. There might be some similar limitation in regard to artificial lighting, bearing in mind that binocular vision played a great part in observation. Subjective methods might be helpful in illustrating this feature.

Mr. L. J. DAVIES, in reply, explained that in mentioning the man in the street he was not tilting at scientific methods. The man in the street was merely asked to go for a walk or a ride and say what he thought; but the real work, which would make his observations of value, was that done by the scientific worker. He believed the time was coming when, in speaking of the brightness of a road area, one regarded that area as being made up of a number of backgrounds. At the present moment an immense amount of work was being done on the subject, both in the laboratories and in the streets. There was every possibility of new methods of lighting being developed for use on the roads, and every possibility of more and more roads being lighted. There was thus room for all forms of work if, in ten years' time, all our roads were to be lighted in the best possible manner. There was always a danger, when technical aspects of these problems were discussed in detail, that the impression might be created that we did not yet know how roads should be lighted! It was necessary to correct this impression, which could readily be refuted by observation of some of the best lighted roads of to-day.

(The remaining two papers read before the Conference, by Mr. Ronald Parker and by Dr. Adolph, will be dealt with in our next issue.—ED.)

Highway Lighting

A study of highway lighting recently presented before the Illuminating Engineering Society (U.S.A.) by K. M. Reid and H. J. Chanon, presents some points of interest. The authors uphold the view that "vision by silhouette" is the chief method of discerning objects on the roadway. They found little difference, so far as visibility is concerned, between incandescent, sodium vapour and mercury vapour lamps. They estimated that 50 per cent. of the illumination is commonly wasted owing to glare, and advocated a complete cut-off of the light at an angle of approximately 10 degres below the horizontal.

Literature on Lighting

(Abstracts of Recent Articles on Illumination and Photometry in the Technical Press)

(Continued from page 341, October, 1935.)

II.—PHOTOMETRY.

285. British Standard Specification for Portable Photometers.

Visual Type (No. 230, 1935).

A revised version of this specification has been issued. The limits of error have been reduced from 15 per cent. to 10 per cent., and the effective range has been modified. An appendix deals with measurements involving large colour differences. The revision has been effected at the desire of the B.S.S. Street-Lighting Committee. J. S. D.

286. Photoptometer for Measuring Acuity at Low Illuminants.

Emile Haas. Rev. d'Opt., Vol. 14, No. 6-7, p. 248, June-July, 1935.

Describes an apparatus the main feature of which is a simple optical system by which the brightness of a test object is made proportional to the length of the filament of the lamp which illuminates it. A window of variable aperture regulates the length of filament exposed to the object, so that the brightness can be measured simply and with accuracy. R. G. H.

287. Notes on Physiological Optics.

D. Couvreux. Lux, pp. 98-106, September, 1935.

This serial article deals fully with visual sensations, measurements of acuteness of vision, appreciation of form, glare, etc. J. S. D.

288. Application: The Use of Photoelectric Cells in Photometry.

P. Fleury and G. A. Boutry. R.G.E., 38, 10, pp. 323-333, September 7, 1935; *A. Gouffé,* R.G.E., 38, 11, pp. 355-359, September 14, 1935.

A comprehensive account of those photoelectric cells now recognised as suitable for photometric work, and some of their most useful applications. W. R. S.

289. The Standardisation of Photoelectric Cells for the Measurement of Visible Light.

H. H. Poole, W. R. G. Atkins. Elect. 115, p. 414, October 4, 1935.

A summary is given of a paper by the authors before the Royal Society dealing with the characteristics of nineteen types of cells with various light sources. C. A. M.

290. Photoelectric Reflection Meter.

Anon. El. Times, 88, p, 308, September 5, 1935.

A photograph and description of a self-contained reflection meter. An annular photoelectric cell has mounted in its centre a calibrated lamp: the cell is screened from direct light. The apparatus is applied to the surface under test, and the reflected light falls on the photocell, which produces a deflection on a microammeter. The apparatus can be calibrated against a surface of known reflection factor. W. R. S.

291. The Photox.

Anon. Frank. Inst. J., 220, p. 401, September, 1935.

A short description is given of a photoelectric cell of the copper-oxide type. Good sensitivity and linearity are claimed, and the response to the spectrum is said to correspond more closely to that of the eye than any other device without special filters. S. S. B.

III.—SOURCES OF LIGHT.

292. Indoor Discharge Lamps.

R. M. Lester. Elect., 115, p. 411, October 4, 1935.

A description, with photographs, is given of cold cathode discharge tube lighting in a private house. C. A. M.

293. Discharge Lamps Without Choke Coil.

Anon. El. Times, 88, p. 308, September 5, 1935.

Describes a high-pressure mercury vapour discharge lamp, in which is incorporated a tungsten filament. This filament is said to stabilise the discharge, thereby dispensing with the need for a choke in series with the lamp, and also to improve the colour of the light. W. R. S.

294. Tungsten Electrode Arc-Lamp for Ultra-Violet Work.

Anon. Rev. d'Opt., Vol. 14, No. 8, p. 293, August, 1935.

The arc is struck between tungsten electrodes in an atmosphere of nitrogen. The electrodes are connected to the terminals of a condenser. A potential of 25,000 volts is applied. The radiation emitted includes the Schumann region from 2400-1250 A. R. G. H.

295. Luminous Tubes for Interior Lighting.

A. Vallat. B.I.P., pp. 178-183, October, 1935.

Available types of luminous tubes are discussed, and a table giving the consumption per metre of those containing neon, argon, and helium is presented. Some typical decorative installations are described. J. S. D.

IV.—LIGHTING EQUIPMENT.

296. Flameproof Lighting Fittings.

Anon. El. Times, 88, p. 400, September 26, 1935.

A photograph and description of a new flameproof fitting. This is one of a series employing a system of cable and coupling which is claimed to have great flexibility. W. R. S.

297. Cinema Arc Supply.

Anon. Elect., 115, p. 346, September 20, 1935.

A brief description is given of polyphase rectifier equipment developed for steady screen illumination values in cinemas. C. A. M.

298. Lighting Developments.

Anon. Elect., 115, pp. 382-384, September 27, 1935.

Details, with photographs, are given of new developments in lighting fittings. C. A. M.

299. New Fitting for Enfield Street Lighting.

Anon. El. Times, 88, p. 308, September 5, 1935.

A description, with a photograph, of a recent design of street-lighting lantern for use with gaseous-discharge lamps. A reflector system of light control is employed, and various adjustments are provided to allow for bends and varying gradients in the road. W. R. S.

V.—APPLICATIONS OF LIGHT.

300. Lighting—Quality and Quantity.

T. N. Riley. El. Rev., CXVII., No. 3,019, p. 434, October 4, 1935.

The article explains briefly how the eye adapts itself

to different intensities, suggesting that within reason, and if other things are equal, seeing is just as certain and as comfortable under low illuminations as under high illuminations. It is then concluded that as much attention should be paid to the quality of the lighting, i.e., absence of glaring sources and of harsh shadows, as to the quantity of light. R. G. H.

301. Departmental Committee on Street Lighting.

Interim Report. H. M. Stationery Office, September, 1935.

This Committee, appointed in June, 1934, now issues its interim report, which deals in turn with administration; technical control; experimental work; and extraneous lighting. The Report is terminated by a series of 20 conclusions in which the desirability of uniform and adequate lighting; the drawbacks of the present system of administration; the necessity for a minimum standard of lighting on traffic routes such that drivers can proceed at 30 m.p.h. without headlights; the importance of maximum contrast between object and background; mounting heights of 25 ft. with 6 ft. overhang; avoidance of glare; preferential use of road surfaces being light in colour and of good reflecting value, etc., are emphasised. J. S. D.

302. Rural Road Lighting.

Gas Times, September 7, 1935.

An illustrated description of a successful experiment in lighting of rural roads in France. J. G. C.

303. Illuminated Traffic Bollards.

Gas Times, September 21, 1935.

An illustrated description of gas-lighted traffic bollards in Hampshire. J. G. C.

304. Highway Lighting—Face to Face.

Earl Whitehorne. El. World, 105, pp. 2,330-2,332, September 28, 1935.

The author stresses the importance of good lighting of the highways in the prevention of accidents. Figures are quoted where increase of lighting has had beneficial results and a decrease of lighting has led to more accidents. It is shown that the additional cost of better lighting is generally more than offset by the saving in loss, damage and insurance costs. The value of demonstration sections is noted, and a definite course of action is recommended. S. S. B.

305. The Important Role Played by Street Lighting in Automobile Fatalities.

Anon. Elect. Engineering, 54, p. 969, September, 1935.

A chart is given showing the percentage of the daily total of automobile fatalities falling in any period of the day. This is compared with the percentage of the total daily traffic occurring at any time. The effect of darkness on their relative values, and also the influence of different grades of street lighting are discussed. S. S. B.

306. Fewer Accidents on Discharge Lamp Lighted Roads.

Anon. Elect., 115, p. 331, September 20, 1935.

Comments are made on the first accident statistics for a recent installation of sodium vapour street lighting units near Paris. C. A. M.

307. Croydon Airport Lighting.

Anon. Elect., 115, pp. 407-408, October 4, 1935.

Full details are given of the various types of aerodrome equipment recently installed at Croydon. Similar equipment is to be installed across India. C. A. M.

308. Lighthouse Illumination.

Gas Times, August 17, 1935.

Describes the use of gas in the lighthouses under the control of the Montrose Harbour Trustees. J. G. C.

309. Industrial Efficiency.

"Works Engineer." Elect., 115, p. 440, October 11, 1935.

The use of the hot cathode discharge lamp for industrial purposes is discussed in detail. C. A. M.

310. Lighting of Foundries.

Anon. Elect., 115, p. 453, October 11, 1935.

A summary is given of a paper by R. W. Daniel on present-day practice in foundry lighting. C. A. M.

311. Printing Press Light Requirements.

Anon. El. World, 105, p. 2,366, September 28, 1935.

After investigation of existing practice, the Chicago Lighting Institute has developed a recommended lay-out for the ordinary two-revolution flat bed cylinder press. Details of this scheme, with resulting illumination values, are given. S. S. B.

312. Architectural Lighting.

R. O. Sutherland. Elect., 115, pp. 359-360, September 27, 1935.

Present tendencies in architectural lighting are discussed. Photographs of recent installations are given. C. A. M.

313. Lighting at the Brussels Exhibition.

P. Brune. Lux, pp. 107-111, September, 1935.

A brief illustrated description of the lighting of the Brussels Exhibition, with views of some of the lighted pavilions. J. S. D.

314. Kingston Guildhall.

Anon. Elect., 115, p. 454, October 11, 1935.

Details with photographs are given of new lighting equipment installed at the new Guildhall at Kingston-on-Thames. C. A. M.

315. Church Lighting.

Anon. Elect., 115, p. 420, October 4, 1935.

Two church lighting installations in London are described with photographs. C. A. M.

316. The New Lighting Bureau.

Anon. El. Times, 88, p. 317, September 12, 1935.

A description with photographs of the Elma Lighting Service Bureau, with an account of experiments now in progress to determine the desirable level of artificial illumination for a given task. W. R. S.

317. A Gas-lighted Demonstration Hall.

"Gas Journal." October 2, 1935.

An illustrated description of a gas-lighted demonstration hall in Dublin. The lighting of a café, also with gas, is likewise described. J. G. C.

318. 22 Foot-candles for Department Store.

Anon. El. World, 105, p. 2354, September 28, 1935.

Full details are given of the lighting installation in an American store. A special built-in design of unit is employed, using prismatic glass plates, some with steel louvres and others flush mounting in the ceiling. An illumination of 22 foot-candles at counter level is claimed, with an expenditure of just under 3 watts per square foot of surface. S. S. B.

319. Commercial Lighting.

Anon. Elect., 115, p. 393, September 27, 1935.

Details are given of a new type of lighting fitting in which six different combinations of glassware are obtained. C. A. M.

320. The Evolution of Outdoor Lighting.

J. Dourgnon. B.I.P., pp. 174-178, October, 1935.

The author recalls early ideas and traces the development of modern methods, including floodlighting; a battery of projectors on wheels for this purpose is illustrated. J. S. D.

321. Floodlighting With Gas.

"Gas Times." October 5, 1935.

Contains illustrations of floodlighting with gas on the occasion of the annual conference of the British Commercial Gas Association at Edinburgh during October. An illustration of the floodlighting with gas of the Coatbridge War Memorial is also given.

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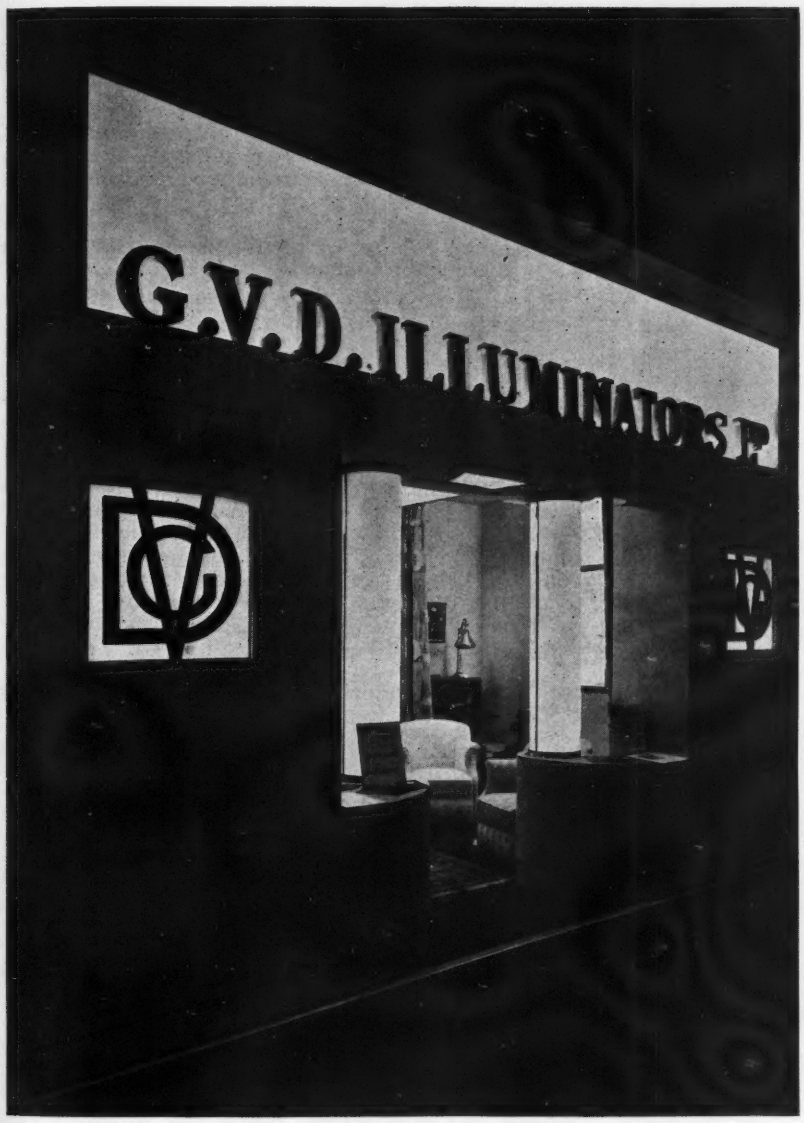

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Recent Patents

(Abstracts of recent Patents on Illumination & Photometry.)

No. 432,962. "Improvements in Miners' Safety Lamps."

Hailwood, E. A., January 31, 1934.

According to this specification a safety lamp is provided with an outer tube-like fitting, within and below the dome, spaced from the upper part of the wick-tube and equipped with upper directing lips in order that air may pass between the wick-tube and outer fitting and be directed to the flame.

No. 433,365. "Improvements in Luminous Electric Discharge Tubes."

The General Electric Company, Limited, March 29, 1934. (*Convention, Germany.*)

This specification relates to discharge tubes filled with a metal vapour which absorbs the radiation which it emits, such as sodium vapour. According to the invention a discharge tube of this type comprises within the main envelope a closed inner tube, which tapers from its middle towards its ends, so that the discharge area is constricted near the middle, more heat is developed and the accumulation of solid sodium in the middle is minimised.

No. 433,577. "Improvements in and Relating to Miners' Safety Lamps."

Jones, T. A., September 4, 1934.

According to this specification, in order to prevent over-heating of the oil chamber and exterior of a miners' lamp and to provide an additional safety air inlet, the lamp comprises an inner shield which is in contact only with a deflector ring, a central outlet above the gauze for the escape of the products of combustion, and an outer bonnet which is not in contact with the top of the lamp. An inner glass chimney, flanged outwardly at the base for mounting, may operate as a combined inner glass and combustion tube without contacting with the gauze. Heat insulating washers may be provided at various points.

No. 433,787. "Improvements in and Relating to Illuminating Devices."

Rivier, L., February 22, 1933 (*Convention, Switzerland*).

According to this specification an illuminating device comprises two or more spaced light sources at equal distances from the axis of a reflector having the shape of a surface of revolution. The light sources are disposed in a plane perpendicular to the axis of the reflector and between the axis and the reflector so that the reflector portions nearest each source reflect each a luminous flux containing parallel rays whereby the polar curve of light distribution exhibits maxima corresponding to the several sources. The device may comprise a spherical bulb having a silvered zone and enclosing a number of coiled filaments. It would seem that the filaments must be mid-way between the spherical bulb wall and the bulb centre.

No. 433,794. "Improvements in Traffic Beacons, Street Lamps, and the like."

Gunning, J. R. W., February 21, 1934, *and June* 14, 1934 (*Cognate Applications*).

According to this specification a traffic beacon or the like comprises a column, having in its head a light source, and a reflecting surface within the column inclined to the vertical and decreasing in width from the top downwards for reflecting light from the source through openings or transparent parts of the column. The reflector may be curved in horizontal section, for example trough-shaped or re-entrant trough-shaped.

No. 433,948. "Improvements in or Relating to Navigation Lights."

Green, H. N., February 17, 1934.

According to this specification a navigation lamp, particularly for air-craft, has a globe formed of a base and a dome, which butt together in a plane perpendicular to the longitudinal axis of the lamp, and provided with a silver or other reflector on its interior surface The reflector may be such as to determine the required angles of visibility in the horizontal and vertical planes. In a port or starboard light the globe may be moulded with a panel extending above and below the horizontal plane containing the longitudinal axis. Part of this panel, on one side of a plane transverse to the longitudinal axis, may be parabolic in transverse section and may be circular in longitudinal section, while the other part may be parabolic in both transverse and longitudinal sections.

No. 434,119. "Improvements Relating to Light-Measuring Instruments."

The British Thomson-Houston Company, Limited, and Ruff, H. R., February 19, 1934.

This specification covers a photometer, foot-candle-meter or the like comprising a casing containing a photo-electric or photo-voltaic cell, a lens for directing light upon the cell, viewing means to enable the operator to determine when the cell is illuminated and a direct-current instrument for indicating the output of the cell.

No. 434,123. "Improvements in or Relating to Electric Incandescent Lamps."

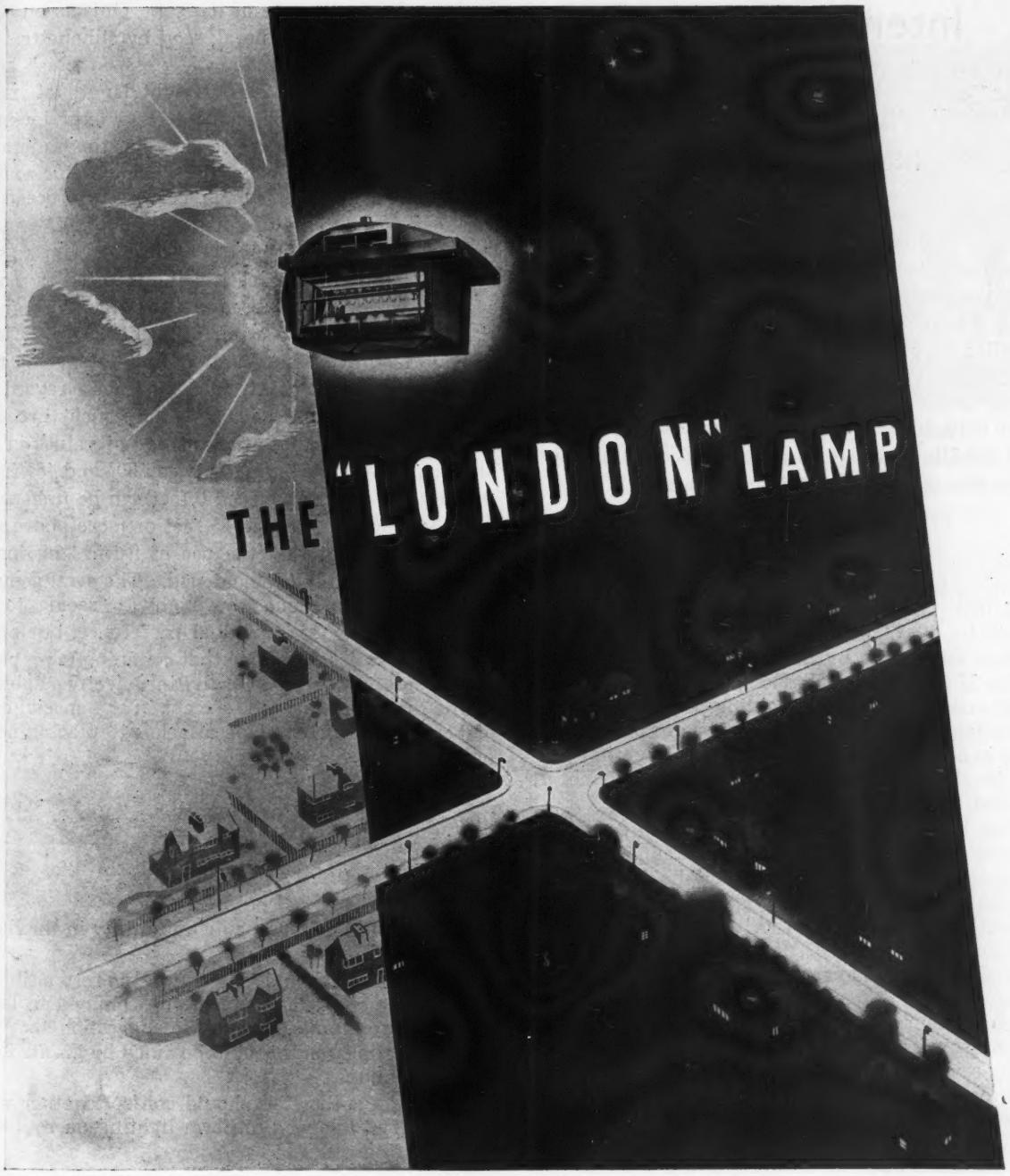
N. V. Philips Gloeilampenfabrieken, March 2, 1933 (*Convention, Germany*).

This specification relates to screened filament incandescent lamps, such as are used for vehicle head lamps. In such lamps, when the filaments are attached to the screen, the filaments frequently burn out at the point of such attachment, and to avoid this, according to the specification, the filament is secured to a curved part of the screen which has a cross section decreasing towards the point of attachment of the filament, and is provided with surfaces which decrease the temperature of that point.

No. 434,164. "Improvements in Miners' or the like Safety Lamps."

Hailwood, E. A., December 27, 1933, *and December* 24, 1934 (*Cognate Applications*).

This specification covers a safety lamp having a guarded air band in the form of separable inner and outer gauzes arranged below or near to the outer glass in which the inner gauze ring is arranged to connect the oil vessel to the upper part of the lamp and carries a separable outer gauze, means being provided on the outer gauze ring for the support of an outer guard ring so that it is impossible to assemble the lamp with one of the gauzes missing.



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Interim Report

of the

Ministry of Transport Departmental Committee on Street Lighting*

The Interim Report of this Committee, which was appointed in June, 1934, was issued last month. In the introduction, it is remarked, the functions of street lighting are grouped under four headings, namely, (a) the convenience and safety of road users, (b) police purposes, (c) the convenience of residents, and (d) special purposes in shopping areas and urban centres. A list of the bodies which have been invited to give evidence is presented, the two first on the list being the Illuminating Engineering Society and the Association of Public Lighting Engineers.

Administration.

Under the heading of "Administration," which has an evident bearing on technical possibilities, it is recalled that power to light roads was given to parish councils by the Lighting and Watching Act, 1894, and to urban authorities by the Public Health Act, 1875. Section 23 of the Road Traffic Act, 1934, empowers a county council to exercise lighting powers in certain circumstances. But all these powers are *permissive*. There is no *obligation* to provide street lighting (except in the case of road obstruction)—though in Scotland a definite obligation is imposed.

It has been urged that lighting of public roads is of equal importance to their efficient maintenance, and that this responsibility should be imposed on local authorities by statute. The grouping of local authorities or confining authority to the larger units has also been suggested. It is recalled that on 31.8 miles of Class I. road carrying heavy traffic there are in use nineteen different lighting systems controlled by twenty-four different authorities, whilst on thirteen miles of arterial road near London there are twenty-seven varying standards of lighting ranging from reasonable adequacy to none at all. The Committee emphasises the importance of reasonable uniformity, and is satisfied that the present system of administration does not ensure uniform and effective lighting on traffic routes.

This leads to the suggestion that the cost of street lighting should be met in some degree from national funds; in that event the Government Department responsible for issuing grants should be empowered to specify an appropriate standard. The total annual cost of providing and maintaining a reasonable standard of lighting is estimated at approximately £300-£400 per mile—75 per cent of the average cost to county councils of the maintenance of Class I. roads throughout the country. If all classified roads in county boroughs and 20 per cent. of classified roads in counties are lighted to the appropriate standard the approximate annual cost would be £3½ millions.

Technical Aspects.

In commenting upon technical matters, the Report records opinions to the effect that "pools of darkness" resulting from even distribution of light on the roadway form a source of danger. Objects on the carriage-way are, in general, seen by silhouette. In order to test effects of road brightness, on which such vision depends, a flat and straight length of road half a mile long has been adopted for experimental purposes. Most witnesses concur that the minimum standard of lighting for roads carrying traffic routes should be such as will enable drivers to proceed at 30 m.p.h. without the use of headlights. A "generously planned Class F" installation, according to the British Standard Specification, is suggested as a satisfactory criterion. Subsequently the Report gives reasons for preferring a mounting height of 25 feet with 6 feet overhang, and a limit to spacing not exceeding 150 feet on straight roads. In regard to glare, it is suggested that fittings are such that the ratio of the peak c.p. to the average of values in all directions downward lying between 30° and 45° from the vertical does not exceed 6 feet can be used with advantage when mounted 25 feet or more above the carriage-way, but that the use of fittings having a higher ratio should be abandoned. The arrangement of light sources along the highway seems to be largely a matter of individual preference, but practically all witnesses agreed that confining lamp posts to one side of the road results in defective lighting and is to be discouraged—except in the special case of bends, where advantage attaches to placing posts on the outer edge of the curve.

Conclusions.

The following are some of the most important conclusions (there are twenty in all in the actual report):—

There should be reasonable uniformity in the lighting of traffic routes.

Consideration should be given to the responsibility for lighting of traffic routes being confined to large administrative units, and to the suggestion that the cost of lighting roads should be aided by grants from national funds.

Adjoining authorities should confer together with the object of securing uniform lighting on routes of common interest.

For traffic routes the minimum standard of lighting should be that which enables drivers to proceed with safety at 30 m.p.h. without the use of headlights; on such routes the lighting units should be of at least the number and power of those required for a generously planned Class F of the British Standard Specification.

A mounting height of 25 feet with 6 feet overhang is desirable; normally the distance between lamps should not exceed 150 feet.

Single side lighting should be avoided except at bends.

Lighting authorities should be advised by an engineer competent to deal with street lighting.

In other recommendations, such matters as the securing of maximum contrast between object and surroundings; the adequate lighting of kerbs and footways; grading the lighting in transition from traffic routes to side streets; and the desirability of good reflection characteristics and lightness of colour for road-surfacing materials are emphasised.

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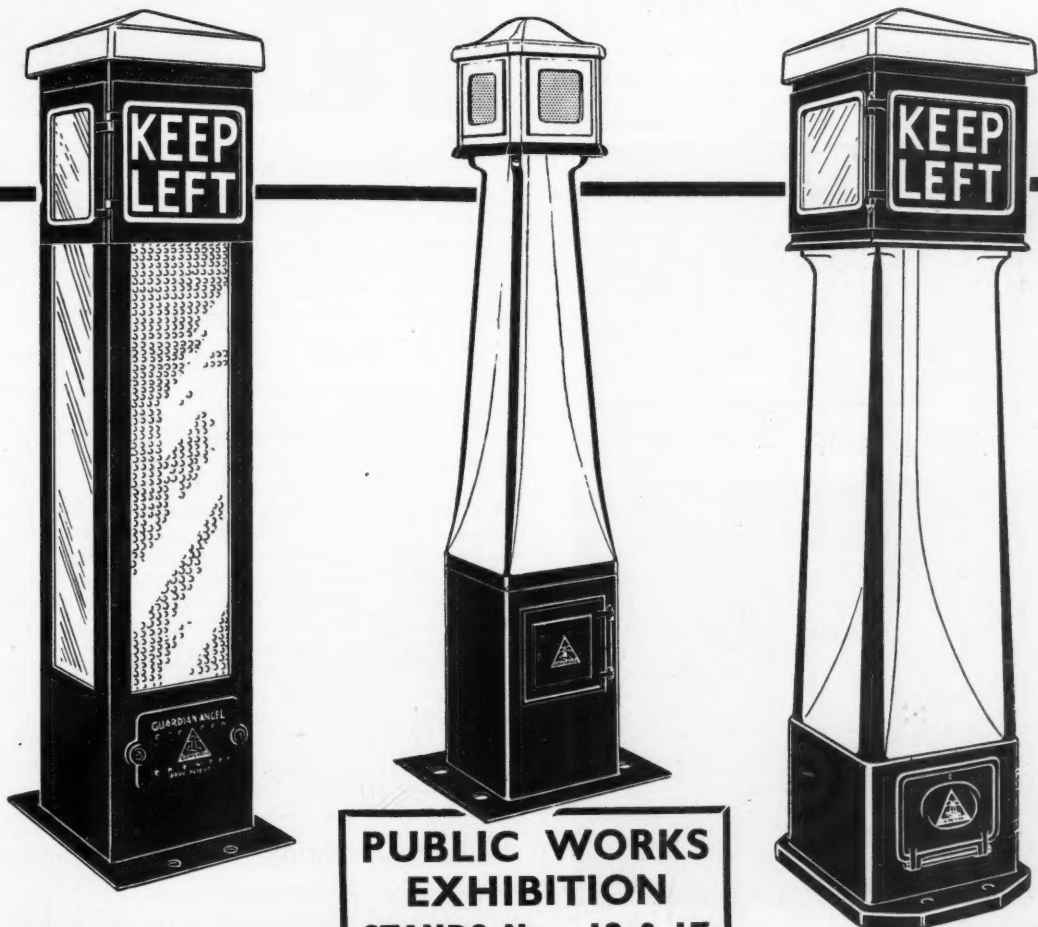
Full specifications of each post and details of minor modifications possible, are quoted in Catalogue (Section 3) a copy of which will be supplied with pleasure.



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TRADE NOTES AND NEWS

How Much is Your Life Worth?

This is the arresting title of a leaflet issued by the General Electric Co., Ltd., and containing particulars of Osram automobile lamps. Motorists do not need to be told of the vital importance of accurate alignment of the filaments in headlights, on which their whole success depends. Osram automobile lamps, besides complying with the specification of the Society of Motor Manufacturers and Traders, can be furnished with a highly ingenious device for securing exact axial alignment based on the superimposing of two images of the filament, one red and one green.

Lighting Trades, Ltd., and Welsbach Light Co., Ltd.; Autumn Catalogue

This catalogue (No. 114) covers a wide range of appliances. The initial pages are devoted to Welsbach and Ironclad mantles, including varieties for use with pressure paraffin, petrol, and air gas burners, and standard burners, nozzles, and accessories. The range of glassware and fittings includes the latest forms of diffusing bowls suitable for semi-indirect lighting. Some of the panel brackets are similar in design to architectural lighting types for electric lighting and a variety of silk shades is included. Outdoor lamps, directional reflectors "inline" floodlighting units with 6 or 10 mantles in line, also figure in the catalogue which is concluded by a section dealing with gas heating appliances.

Sieray-Dual Lamps at Preston

The above photograph illustrates the first installation at Preston (Lancashire) of the new Sieray-Dual Lamps, comprising a combination of an electric discharge tube and a tungsten filament, described in our last issue (p. 348). The lamps are mounted in Preston-Sieray lanterns and are spaced 140 ft. apart. The mounting height is 25 ft. and the projection over the roadway, which is 40 ft. wide, is 6 ft.

Night photograph of the new pier at Dun Laoghaire (Irish Free State) lighted by Holophane 500-watt Duo Dome Refractor Units in ornamental lanterns. These units furnish an assymetrical beam of 180°, thus concentrating the rays on the roadway and avoiding stray light on the water on either side. The posts are 22 ft. high and the height to the double lanterns is 20 ft.

F. H. Pride; Extensions of Business

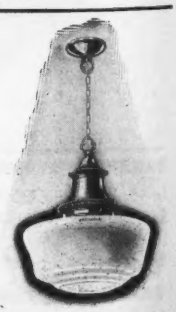
The business of Messrs. F. H. Pride, illuminating engineers, 69-81, High-street, Clapham, S.W.4, has recently been extended by the establishment of a special section devoted to the design and construction of all forms of electrical gear required in the equipment of modern cinemas, notably projection control gear, dimmer banks, switchboards, etc.

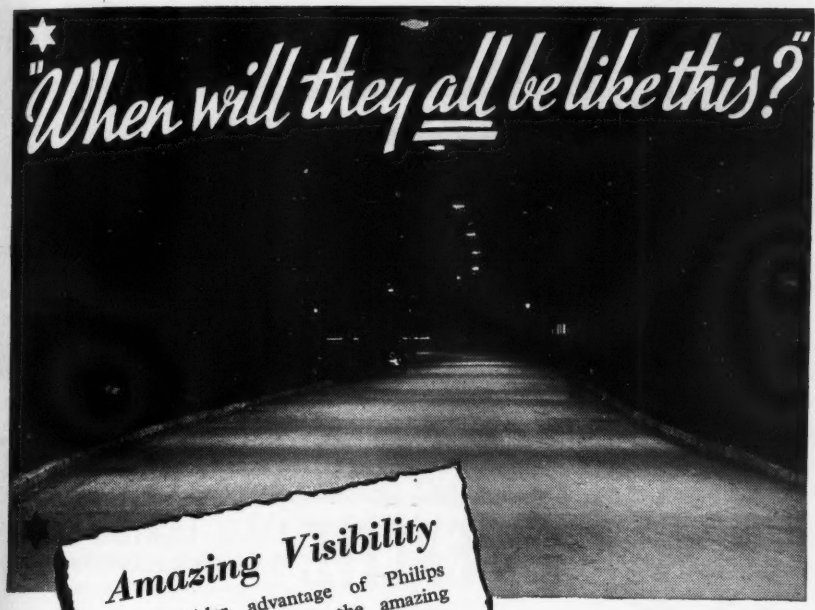
The new department is under the control of Mr. B. T. S. Gamble, a member of the Illuminating Engineering Society, who has a wide experience in this branch of the industry, and is well-known throughout the engineering profession.

We understand that Messrs. F. H. Pride have just completed a number of important cinema contracts for lighting fitments, panels, dimmers, or other accessories. Amongst the theatres thus supplied are the Theatre Royal (Dublin), Gaumont (Manchester), Playhouse (Louth), Cabot (Bristol), etc.

Hailware Lighting Fittings

The adjacent illustration is one of a variety illustrated in a recent "Hailware" list. These enclosed diffusing fittings are now very popular. There are also shown cylindrical designs and ingenious wall and ceiling fittings.

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Amazing Visibility
A particular advantage of Philips "Philora" lighting is the amazing visibility it gives, coupled with freedom from glare. Yet the consumption of Philips "Philora" sodium lamps is very little. Investigate the advantages of "Philora" lighting.

asks The Daily Express *in its campaign against the Death Trap Roads of Great Britain.*

The illustration shows an arterial road at Liverpool lit by Philips Philora street lighting system. The result is an evenly lit, shadowless surface, throwing up into strong contrasts any object upon it. Yet Philora lighting is 50% more economical than normal methods of street illumination.

SEE THAT THE ROADS UNDER YOUR CARE *are lit by*

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SODIUM LIGHTING

AND MERCURY LIGHTING

"THE SAFEST STREET LIGHTING IN THE WORLD"

PHILIPS LAMPS LTD., 145 CHARING CROSS ROAD, LONDON, W.C.2.

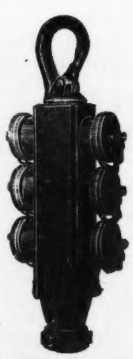
Nine Years' Progress at Croydon

At a meeting of the Thornton Heath Ratepayers' Association some interesting data in regard to the growth of the Corporation Electricity Department were given. During the last nine years the total revenue has been approximately doubled, the average price per unit nearly halved, and the units generated increased about five times, whilst the units applied to public lighting have increased from 813,000 to 2,500,000.

New Lighting in Rochester

The accompanying illustration shows an installation of Philips "Philora" 400-w. mercury lamps in Corporation-street, Rochester. The poles are spaced at 200 ft. apart, and the bi-multi fittings are mounted at 27 ft. The installation was carried out by the Kent Power Co., Ltd., in co-operation with the Electric Street Lighting Apparatus Co., and under the supervision of Mr. H. B. Harvey, M.I.E.E.

"Philora" street lighting in Rochester.



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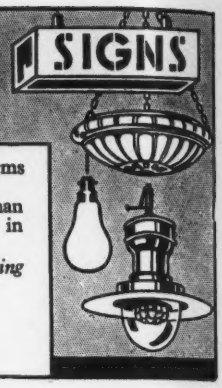
A DIRECTORY OF LIGHTING EQUIPMENT



We invite applications for spaces in this new section of the journal. Particulars of terms for each space (approx. 1 inch deep and 3¼ inches wide) are given below.

These terms are equivalent to **half our ordinary advertising rates,** but not less than 12 successive monthly insertions can be accepted on this basis, and amounts are payable in advance.

Payment for an advertisement in this section entitles the advertiser to receive *The Illuminating Engineer* during the period of the contract.

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1

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Seamless Steel Lighting Standards
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The Foundry, Canterbury

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employing light sensitive
PHOTO-ELECTRIC CELLS
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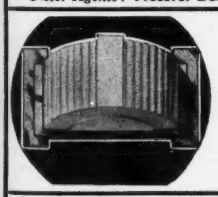
23



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LINOLITE
34 years young
Regd. *Scientific*

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Winches, Lamp Lowering and Suspension Gear, Searchlights *(largest and smallest in the world)*, Mirrors, Lenses, Carbons, Floodlights, Flexible Couplings (all-metal), Wire Ropes, Headlights,

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ADJUSTABLE FITTINGS FOR EVERY USE.
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Selenium Layer Type (Brit. Pat.) round or square, for all kinds of light-sensitive apparata.
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Shop Windows Dress Parades Ballrooms Tea Lounges

WARDLE ENGINEERING Co., Ltd.
OLD TRAFFORD, MANCHESTER
STREET LIGHTING EQUIPMENT. TRAFFIC SIGNALS 42
PRISMAT BULKHEAD FITTINGS. FLOODLIGHT PROJECTORS
WORKSLITE REFLECTORS. WARDELYTE GLASSWARE

39 For every type of GAS LIGHTING — SUGG WESTMINSTER — When you want the best! CHAPTER ST. S.W.1

"PHOTRONIC" Photo-electric ILLUMINATION METERS BY **WESTON** 43

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40 "BARLUX" TUBELAMPS
TUBELIGHT SALES LTD · 23 PANTON ST · S.W.1

"THE FITTINGS THAT IMPROVE WITH AGE"
WOODFYT
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10a, NEWMAN STREET, W.1
(Museum 7325)
Catalogue sent on application 44

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N.B.—The numbers are those attached to individual entries in the Directory (See pp. 404-406.)

National Safety-First Congress (1935)

A Report on the Proceedings of the above Congress, held in London during May 29-31 of this year (price 5s.), has been published by the National "Safety-First" Association. It contains the paper on Street Lighting and its Relation to the Safety of Roads read on that occasion by Mr. S. B. Langlands, and a summary of the discussion.

SIMPLEX
Industrial, Commercial & Street Lighting Shopwindow

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SCIENTIFICALLY DESIGNED
SIMPLEX ELECTRIC CO., LTD.
Head Office: 159, GREAT CHARLES STREET, BIRMINGHAM, 3

"LUX"
(La Revue de l'Eclairage)

WE have pleasure in announcing to our readers that we have entered into an arrangement to receive subscriptions for the French Journal "Lux" (La Revue de l'Eclairage). The subscription per annum is 30 francs, the approximate equivalent of which in English money is Seven Shillings and Six Pence (7/6).

"Lux" is the only French journal which specialises in all aspects of lighting; it is the official organ of the Association Francaise des Ingenieurs de l'Eclairage (equivalent to the Illuminating Engineering Society in France).

It furnishes a complete record of interesting developments in lighting in France and on the Continent. It is fully illustrated and in particular devotes a considerable number of its pages to Decorative Lighting.

By studying these articles and the numerous photographic reproductions of modern lighting installations the reader can readily gain an excellent impression of French methods and practice in matters of Illumination.

Applications for subscriptions will be received by "The Illuminating Engineer," 32, Victoria Street, London, S.W.1.

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Corporation Street, Birmingham, under the new system of Gas Lighting.

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means A1 light for Birmingham

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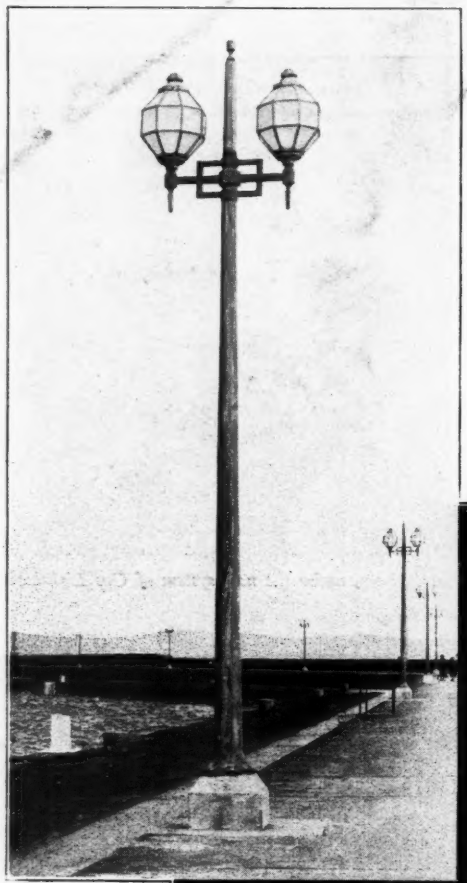
The respective widths of the carriageways in New Street and Corporation Street are 35 ft. and 40 ft. Pairs of lamps, each yielding about 3,000 c.p., are mounted 7 ft. apart, and spaced at intervals of 70 ft. The height of the lamps above the surface of the roadway is 26 ft. 6 in.

Please write for a copy of our street lighting booklet "To every public man and woman" — it's free — to the address below.

THE BRITISH COMMERCIAL GAS ASSOCIATION, *28, Grosvenor Gardens, London, S.W.1.*



HOLOPHANE LIGHTING AT EAST PIER DUN LAOGHAIRE

THE HALLMARK OF Holophane GOOD LIGHTING

GIVE MORE THAN EVER NOV. 11 REMEMBRANCE DAY

NIGHT PHOTO OF EAST PIER, DUN LAOGHAIRE, NR. DUBLIN, LIGHTED BY HOLOPHANE DUO DOME REFRACTORS IN OCTAGONAL LANTERNS. (Top left.) SHOWS THE LANTERNS AND POST IN DAYLIGHT.
(Night Photo by the courtesy of E. S. B., Dublin.)

AN OUTSTANDING INSTALLATION OF LIGHTING WHICH TRANSFORMS DUN LAOGHAIRE PIER INTO A SHINING RIBBON OF LIGHT.

THE SPECIALLY DESIGNED ORNAMENTAL LANTERNS ADD A DECORATIVE FEATURE TO THE PIER IN DAYLIGHT, WHILST AT NIGHT THE **HOLOPHANE** AXIAL TYPE **DUO DOME REFRACTORS** ENSURE AN EFFICIENT LIGHT DISTRIBUTION.

THIS IS ONE OF MANY SPECIAL ORNAMENTAL LANTERNS WHICH OUR DESIGN DEPARTMENT ARE PREPARED TO SUBMIT FOR LIGHTING OF GARDENS, PIERS, PROMENADES, ETC., ON REQUEST.

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